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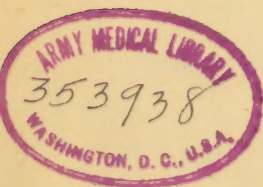
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SITUATION, CONSTRUCTION, VENTILA-
TION, DRAINAGE, ETC.

BY

HENRY HARTSHORNE, A.M., M.D.,

Formerly Professor of Hygiene in the University of Pennsylvania, etc.



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A time there was

When every rood of ground maintained its man:
For him, light labor spread her useful store—
Just gave what life required, but gave no more;
His best companions, innocence and health.

Goldsmith.

Type of the wise, who soar, but never roam;
True to the kindred points of Heaven and Home.

Wordsworth.

OUR HOMES.

CHAPTER I.

INTRODUCTION.

WE should need no Darwin to teach us that man is a part of Nature. Though sovereign in the creation, his is but a limited monarchy, with an unwritten but inexorable constitution, which he must obey, or suffer the penalty. Apart from human interference, there is in nature a balance of formation and destruction, of life and death, food and waste, making a perfect natural economy everywhere. Man comes in with his artificial constructions, and sweeps away much of this economy of nature. Under his tread the green earth grows bare. His habitations exclude multitudes of the lower and lesser creatures, whose ordained functions as natural scavengers are thus impaired or annulled.

Hence comes foulness of the earth, water and air; stench, miasma, pestilence. A guerilla warfare seems to be waged all around the invader of Nature; yet

man's conquest of the world is legitimate. What is wanting? Simply that our reason should be used in counting the true cost of civilization, and meeting all its conditions as they exist, wisely. We must maintain or restore the original balance of primeval nature, by providing for the reappropriation of the products of life and the results of death and decay around us.

Chiefly, the evils to be guarded against belong to the deterioration of the atmosphere and of drinking-water, under the influence of decaying matter. Every human being gives out constantly from his lungs, skin, and otherwise, about as much as is from day to day received by him as food, drink, and air of respiration. We take air and water, and grains, fruits, roots, flesh, etc., into our systems; we organize or consume them, and then throw them out again to be rapidly decomposed. The higher the life they have attained in us, the deadlier poisons they become in their effete molecular death. Thus *crowd-poison* breeds typhus fever, and promotes typhoid fever, diphtheria, cholera infantum, yellow fever, and malignant cholera; nay, gives special aid and sustenance to all contagious and epidemic disease-causes, — such as those of small-pox, scarlet fever, and the rest, and contributes greatly to the mortality from pulmonary consumption, pneumonia, and nervous affections, especially those of children.

How we are to live, then, not as wanderers of the forest, nor yet as hermits, but in society, without abridging our lives and multiplying the "ills that flesh is heir to," is the question. The imperfection of the manner in which this question has been, so far, generally answered, may be judged of by a late account given by the eminent statistician, Dr. Farr, of the proportion between population-density and mortality, in the six hundred and nineteen districts of England and Wales, from 1861 to 1870. In seven groups of those districts (excluding London), the number of persons to a square mile is, respectively, thus:—166, 186, 379, 1178, 4499, 12,351, 63,823. The annual mortality for each 1000 inhabitants in the same districts is, 17, 19, 22, 25, 28, 32, and 39. In other words, according to these results, the nearer people live to each other, the shorter their lives. In fifty-three districts, the average proximity of residents is 147 yards, and the mean duration of life is 51 years; in 345 districts the proximity is 139 yards, and the mean length of life 45 years; in 137 districts the proximity is 97 yards, and the length of life 40 years; in forty-seven districts the proximity is 46 yards, and life-duration 35 years; in nine districts, with an average proximity of 28 yards, the mean duration of life is 32 years. In Manchester, the proximity is 17 yards, and the mean length of life 29 years; in Liverpool, the proximity reaches the maximum of seven

yards, and the duration of life its minimum average, 26 years.* This brevity of human life was exceeded, it is true, a hundred years ago, in many places,—an important improvement having, in our own time, begun, which needs yet to be very greatly extended almost everywhere.

Our question, “*How shall we have Healthy Homes?*” may be best considered in view of the following topics concerning human habitations: I. Situation; II. Construction; III. Light; IV. Warmth; V. Ventilation; VI. Water Supply; VII. Drainage; VIII. Disinfection; IX. Population; X. Working-Men’s Homes.

* *Popular Science Monthly*, March, 1879.

CHAPTER II.

SITUATION.

“**G**OD made the country, and man made the town.” So wrote the poet Cowper. With more philosophy, he might have seen that it was *meant* that man should build towns; only, in this, as in everything else, he should obey the laws of his creation. We ought not to make our towns so different from the country as they are.

No doubt, for healthfulness of situation, a rural locality is usually the best; yet not always, for, near a malarious swamp, or a shallow, sluggish stream, causes of disease exist, from whose influence the densely built city may be free. Charleston city is, in most seasons, more safe from injury to health than the rice plantations of South Carolina. Near Philadelphia, many now living remember how the region liable to autumnal fevers has been “crowded out” by the extension of the city, until now it can scarcely be said to exist within its large extent.

Suppose a person with unlimited means to desire to choose a salubrious site for a residence. He will

reasonably leave the city. He will then be especially careful to avoid a malarious locality. Such will generally be found on low grounds of *alluvial** formation, and in the vicinity of marshes or sluggish rivers, where moist earth is exposed from time to time to the rays of the sun. Apart from specific "malaria," also, the soil has considerable importance. It acts by its absorption and radiation of heat, by the reflection of light, absorption of water, and movement of water through and under it; formation of dust, and its chemical character, affecting the air about it. Pettenkofer has shown that a cubic foot of soil may contain one-third of a cubic foot of air; and Bousingault has found in this "ground-air" a great deal of carbonic acid gas.† While in the ordinary atmosphere out of doors the amount of this gas is from three to five parts in 10,000, in the air of a field recently manured there existed 221 parts in 10,000; in forest land, 86; loamy subsoil, 82; sandy subsoil, 24 parts.

Worse gases than carbonic acid may permeate the soil under some circumstances. Graveyard air, as interments are generally managed, is known to be unwholesome in its influence. This results from the gases of decomposition which escape through the

* That is, not hard rock, but such as is made by the washing of rivers, etc., in past times.

† The same gas which is produced by breathing and burning fuel in the air.

soil. Drains, cess-pools, and sewers, when allowed to leak or pour their contents upon or into the ground, pollute it so that it may, when saturated, give off very injurious effluvia. Prof. Pettenkofer mentions an instance of illuminating gas, from a leaky pipe, penetrating through the earth to a distance of twenty feet, and so saturating the basement of a house as to cause the death of one of its inmates.

It is wonderful, however, how much is done by the earth to purify the foulness which, by necessity or from neglect, is allowed to enter into it. This may well be regarded as one of the providential means of adaptation of the world we live in to the needs of its inhabitants.

But ground-water, near the surface, injures the healthfulness of a situation more frequently and largely than ground-air. Sometimes the very efforts made to please the eye by picturesque effects may almost ruin a locality as to salubrity. Prof. R. Bartholow has shown* how this has been done in some of the suburbs of Cincinnati, not only by streets and roadways obstructing the surface drainage, but by artificial lakes, whose beauty to the eye is but a disguise for the accumulation of causes of malaria.

Dampness of soil, even if not specially contaminated, is unwholesome. It has been shown, both in Great Britain and in this country, to promote con-

* Lecture on the Hygiene of Suburban Life, 1878.

sumption of the lungs, besides the known liability of persons living in damp places to rheumatism and "colds." A certain relaxing effect, also, is felt by many people where the locality is damp, most of all in warm weather,—the very opposite of the bracing, tonic influence of a high and dry situation.

Of different kinds of soil, sand absorbs and retains very little water; clay ten or twenty times more; and "humus," or rich arable earth, forty or fifty times as much as sand. Hard sandstone rock, and the harder limestones, as well as the solid granite and trap rocks, allow very little movement of water through them. Very frequently, too, these rocks slope so as to let the water run over them and drain away. Clay is more likely to lie flat, so as to have water accumulate upon it; hence clayey soils are apt to make damp situations. The worst soil of all for building is what is called *made ground*, composed of the refuse from various places, filth of houses, decaying vegetables, etc., carried and deposited to fill up low spots in the suburbs of towns. Observation shows that at least three years will be required for such earth to undergo the changes necessary to make it innocent of unwholesome emanations; and even after a longer period, it is impossible to be sure of its healthfulness. Just as a question of health, we may, because of their porosity, prefer sand, gravel, or loose limestone, to anything else, upon which to build a house; although

even upon such ground a right construction is needful for this kind of security as well as for permanence.

Our ideal site may be, in order to combine the greatest sum of advantages, upon a gentle slope, or the side of a hill not too steep, looking, in our part of the world, towards the south or south-west. It must not, even though upon a height, be near a marsh or sluggish river bank, as the vapors lifted by the morning sun and settling again with the decline of day, may be wafted by the winds hundreds of yards up the sides of the most beautiful lawn-covered hills. A grove of trees will, it is true, afford a very considerable protection from malaria, by intervening between a house and a source of its emanation. But, then, the inhabitants of such a locality must be very careful in their excursions, especially near sunset and sunrise, in the spring and autumn.

How many thousands of men are unable to make any such choice as we have mentioned, of a rural home! In the cities, also, there is much room for selection, on the part of those who are not limited by want of means. Elevation, in some cities, as Cincinnati, Baltimore, and even Philadelphia, varies sufficiently to make quite an important difference. We should always, of course, when possible, choose the higher part of the town for a dwelling. A wide street will be the best. No street should be allowed

anywhere of less width than twice the height of the houses upon it ; although so stringent a rule is probably nowhere, as yet, enforced. The *least width at all tolerable*, in the poorest part of a town, should be fixed at the height of the highest dwelling upon the street.

A street with *trees* lining it is made thereby more healthy. There is no doubt at all that the leaves of all ordinary plants and trees improve the air for our breathing, by taking from it carbonic acid gas and returning to it fresh oxygen. On the sunny side of the street, too, it is advantageous to have the glare of an American noonday mitigated by a moderate, but not excessive, shade. A corner of two streets will afford the best circulation of air.

Houses erected back to back are always to be avoided. Squares built upon two (or even four) sides, with their gardens meeting each other, and also with at least small side lots between them, and each standing back twelve or fifteen feet from the sidewalk, with grass and shrubbery in front, will meet all the most desirable conditions for a city residence. Such can be, at present, obtained in our large cities only by the rich. But, if common understanding or law should make it usual to lay out and build upon only such lots in all new and growing towns, except in their strictly business portions, it would not be difficult for breathing-spaces to be perpetually main-

tained. How beautiful an effect may result in a city from such an open plan of construction, may be seen in East Avenue, and some other streets, in Rochester, N. Y. Yet that this is only one of the necessary conditions of the salubrity of towns, is shown by the reports of mortality in that city, from preventable diseases, owing to defective drainage and sewerage.*

On the subject of tenement-houses and working-men's homes, their situation and construction, we shall remark hereafter.

* See the *Sanitarian*, October, 1879, page 477.

CHAPTER III.

CONSTRUCTION.

OUR purpose here is not to consider the architecture of houses with regard to ornamental effect, but only the conditions requisite for healthy dwellings. Under this view, of the materials commonly employed, either wood, brick, or stone may be made to answer. A frame house allows the most air to penetrate its walls, unless they are specially protected ; and, in a climate with severe winters, this is trying to delicate people. Those who begin with good health usually find an *airy* mode of living agree with them better than the pent-up atmosphere of most furnace-heated houses. Moreover, a frame house having double walls, with stone or brick foundations, good plastering, and tightly-jointed timbers, may be made as little permeable by air as it is desirable for any house to be.

•Brick is porous, and allows more atmosphere and vapor to pass through it than many people are aware of. So do sandstone, mortar, and cement. Marcker and Berthold, in Paris, lately found that these sub-

stances allow gases to pass freely through them, while granite, slate, limestone, and marble are impervious. Prof. Pettenkofer, of Munich, has exhibited this permeability very well by a simple experiment. A cylindrical piece of mortar, half lime and half sand, is covered with melted wax (making it impenetrable by air), except at the two ends. A funnel is then fixed upon each end. By blowing through one of these funnels, a candle-flame opposite the other end may be blown out. If water be drawn into the mortar by suction through the funnels, so as to fill its pores, air can no longer be blown through it. This represents the condition of damp walls of houses. Another experiment of the same observer is made with compact brown sandstone. A block of this sub-

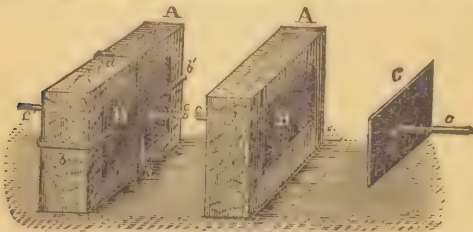


Fig. 1.

stance (A, Fig. 1), fifteen inches long, twelve wide, and four and three-quarters thick, has on each side a depression (B, Fig. 1) one-fourth of an inch in depth. In each of these depressions is placed an

iron plate (C, Fig. 1), in which is inserted an iron tube (c, Fig. 1). Melted resin is then poured around the edges of the plates, and the stone is thickly covered with asphalt, so that it is made impervious, except through the tubes.

When one of these tubes is connected with a burner of a chandelier, and the gas is turned on, the pressure is sufficient to force the gas through the block of stone and the other tube, so that it can be ignited beyond the latter.

This permeability of the walls of houses Prof. Pettenkofer believes, no doubt correctly, to be advantageous. If we were sealed up tightly, except so far as intentional openings afford access to the air, some people's fear of draughts and cold, if it did not endanger suffocation, might at least aggravate seriously the evils of defective ventilation. Here may be mentioned the unsuitableness (in a sanitary sense) of *wall-papers* in any unless the largest and best-aired apartments. Not only green wall-papers, but those of several other colors, have been shown not unfrequently to contain arsenic in sufficient quantity to produce poisonous effects upon those long confined in their rooms. Moreover, papers *absorb organic matter* in considerable amount, and they are therefore particularly objectionable in sick-rooms, and, indeed, in any chambers in which persons sleep. Whitewashed, calcimined, or painted walls

are more wholesome than those covered with any kind of paper.* Even paint interferes somewhat with the permeability of walls.

Nothing is more important in the construction of a house than that its foundations shall be protected from dampness. A wet cellar is a fatal fault, from the hygienic standpoint. Under-drainage may correct this when it exists. A good under-layer of concrete † will be of great service, whatever the soil on which the house is built. If it be still suspected of dampness, an asphalt flooring for the cellar may be used, supplemented, if need be, by one of zinc for the first floor over it. A cheap material for making cellar floors practically water-proof is made by mixing together two parts of coal tar with one part of pitch, and adding to each bucketful three handfuls of quicklime. Eassie, ‡ an excellent authority, recommends vitrified stoneware tile as furnishing the best "damp-proof course," made in thicknesses from an inch to an inch and a half, and perforated, so as to ventilate the space between the ground and the joists of the floor, and to prevent dry rot in the timbers.

* Worst of all is the really nasty practice of covering old papers again and again with new ones, sometimes three or four times in succession. They should always be scraped off before renewal.

† A compound of broken stone, pebbles and mortar, much used for such purposes.

‡ Sanitary Arrangements for Dwellings, London, 1874.

Dr. B. W. Richardson, of London, in his "*Hygeia, a City of Health*," recommends that every house should be built upon arches of solid brick-work, so as to allow air to pass freely and constantly beneath its foundations. Undoubtedly, this is a reasonable suggestion, and no more Utopian than many other of his proposals for the construction of his ideal city.

No flooring of wood, at all events, should be laid directly upon the surface of the ground, but the joists of the "ground floor" should be raised at least two or three feet by stone or brick foundations.

Double walls are better than thick walls. Even as a protection against changes of heat and cold, the layer of air between the outer and inner wall will be a slower conductor than the solid wall would be. The occasional omission of a brick near the lower part of the house, or the insertion of perforated bricks at regular intervals under the basement flooring, will allow of a movement of air through the interspaces which will contribute to dryness as well as to ventilation. The distance between the outer and inner wall may be two or three inches, the open space commencing above the foundations.

Roofing must, of all things, be made and kept tight, free from leakage. Some slope is necessary for drainage of rainfall, but it need not be great. Mansard roofs, now so common, do not seem to be at-

tended by any inconvenience. Dr. B. W. Richardson advises that roofs shall be covered either with asphalt or flat tile; but tin, zinc, or slate, well placed and kept in repair, will do. If rain-water is to be collected for use, slate will make the best roof.

Other points in the construction of a healthy house yet remain to be mentioned. Every room for day or night use should be as large as its owner can afford, and with an abundance of windows and doors, for air and light. Each room should have, if possible, at least one window on each of two of its sides. With opposite windows, a small room with a low ceiling may be well ventilated; but this involves more draught than many people wish; and a large room may always be aired with less perceptible movement of the air than a small one. Windows should be high, reaching almost to the ceiling, and opening both at the bottom and at the top, unless the casement or "folding-door" arrangement of the sash be preferred, which answers very well. Every room in the house intended to be occupied should have in it an open fireplace. This is left out, to a great disadvantage, in building a great many modern houses. Especially is it important for an open fireplace to be in every sleeping chamber. For a sick person, the difference between a wood-fire on the hearth, or even a wood-burning stove, and the usual heated air, or coal-stove in the room, is immense. It may, in crit-

ical cases, make the turning-point between death and recovery. Besides this, an open chimney, without a fire, is an excellent aid to ventilation. Even a stove-pipe hole, left open, in a sheet-iron or other cover for the fireplace, will have a considerable influence in **changing the air of a room.**

All fireplaces and furnace-heaters may, to advantage, be placed near the centre of the house. Water-closets should be located always on the outside, so as to have a window or windows opening to the air. An extra and excellent precaution is to have a small wing or annex, expressly for water-closets, which are placed over each other on different stories; each being separated from the house by a vestibule with double doors.

Richardson, in his *Hygeia*, places the kitchen in the uppermost story of the house. For this the principal argument seems to be, that thus all smells may be kept out of the house itself. A kitchen-wing, at the rear of the dwelling, may be made to answer this purpose. While coal is used for fuel, its weight will be a serious obstacle to its elevation to a third or fourth story kitchen. When gas comes to be used generally for cooking (as may shortly be the case), this objection will be removed. This is, however, rather a question of convenience than of health, as kitchen smells, when proper care is taken of refuse, are not specially injurious, although often unpleasant.

If a basement, below the ground level, is used for a kitchen or otherwise, an area several feet in width should be kept around it, to preserve it from dampness. Our remarks concerning drainage are reserved for another place.

What has been so far said upon the construction of houses for health has been meant to apply mainly to those whose owners can afford to make them what they wish. But the same principles, exactly, apply essentially to all dwellings, from the palace of the emperor down to the hut of the laborer, or the cabin of the forest pioneer. In all, the great requisites are dryness, air, sunshine, and sufficient protection from the cold. Some of these, at least, as air and sunshine, are most readily excluded from parts of the largest houses. What experience has shown to be necessary in these, most of all when inhabited by a number of persons, may be understood by referring to some recent sanitary legislation in New York.

The new Tenement-House Act, 1879, gives the Board of Health of that city important power over these structures. The plans of all new buildings must be submitted for its approval, and it is required to secure the following conditions:

1. At the rear of every house there shall be a clear, open space of not less than ten feet.
2. No one continuous building shall occupy more than 65 per cent. of the lot.

3. The total area of window space in every room communicating with the open air shall be one-tenth of its superficial area, and the upper half shall be so made as to open full width.

4. Air-shafts must communicate with every room having neither external windows nor fireplace.

That "shutting up," even in the variable and extreme climate of the northern United States, is not, as some persons think, the great necessity for health, is amply proved by the fact that, during the Civil War, tent hospitals (*i. e.*, hospital tents) were found to give better results in the treatment of wounded and sick soldiers than the very best constructed and managed large hospital buildings. Not a few consumptives have owed the prolongation of their lives for years, and some, complete recovery, to their resorting, for months together, to camp life in the midst of the primeval forest, where the Eden-like atmosphere, breath of the pine woods, untainted mountain water, and simple food and habits of life restore the strength exhausted by artificial living. In short, the greatest fault of the personal hygiene of our civilized habits may be summed up by saying, *we live too far from Nature.*

CHAPTER IV.

LIGHT.

ALTHOUGH we are not, like plants, absolutely dependent for our growth upon the rays of the sun, yet we share with all nature their benign influence ; and if they are withdrawn constantly, health suffers. Miners, passing all their days underground, as in some of the mines of Europe, are usually short-lived, and prone to diseases of debility. A physician in New Orleans, during one of its epidemic years, reported that there were more than six times as many cases of yellow fever on the shady as there were on the sunny sides of the streets ; and a similar account was given of the prevalence of cholera at Buffalo, in 1849. Barracks for soldiers, so built that no sunlight enters them, have proved extremely unhealthy. For the sick, especially, who cannot leave their rooms, it is of great consequence to have the sun's rays penetrate their rooms freely a part of every day. Scarcely any exception exists to the benefit of sunshine in the sick-room, besides cases of acute inflammation of the eyes or brain. In chronic inflammation of the eyes,

the practice, once common, of shutting the patient up for weeks in a dark room, has been almost entirely abandoned; it being found that the depressing effect upon the general health of the body more than counterbalances the good results in treatment of the eyes. Of all rooms in the house, the *nursery* should be the brightest and sunniest. Therefore, a house is best placed so as to front north or south (preferably, in northern latitudes, the latter), in order that the rooms on each side may be shone upon during some part of the sun's course every day. If a house be built diagonally, there is an unequal distribution—some rooms are very sunny, and others never have any sunshine at all. Fronting east or west, particularly in cities the latter, will do well enough in many situations.

The ancient Romans are said to have had terraces on their houses, called *solaria*, upon which to bask in the sun and air. Sun-bathing is sometimes remedial in sickness. I have known a severe attack of neuralgia to be relieved by the patient's sitting or lying in the direct light of the sun. All convalescents from illness gain most rapidly when they can get out into the full light every day.

Dr. Arthur Downes and F. P. Blount, on the basis of experimentation, reported in a communication to the English Royal Society, assert that light prevents or retards the development of *bacteria*, and of the mi-

croscopic fungi associated with putrefaction and decay. This preservative quality is most powerfully shown by the direct solar rays; although it is possessed, in a less degree, by ordinary diffused daylight.

Yet there is such a thing, not only in the tropics, but in temperate regions, as too much sunshine. Heat-stroke, it is true, very frequently occurs in the shade, in people predisposed to it, from the oppressive effect of a heated atmosphere. But our midsummer sun may well be tempered by the cool shade of trees not far from our dwellings. American travellers in England notice, at first with surprise, how little shaded are the rural homes, even of the wealthy, as compared with those of the United States. But a season spent under the veil of mist and cloud which so often hides or dims the sun in that country, makes it intelligible that too little rather than too much sunshine is the danger there. No more unreasonable impost than the English *window-tax* (proportioned to the number and size of windows in dwellings), was ever invented. But we may, in America, have our houses too densely shaded. This is a not uncommon mistake. The effect of it is, not only exclusion of sunlight as such, but dampness of the roof, walls, and interior of the house. While sentiment and association may plead with us to "spare that tree," whose venerable trunk and spread-

ing branches we have loved all our lives, yet we must not allow too deep a shadow to chill the space beneath it. A safe rule is, never to have trees so thick near a house that every part of it, which, from position, is accessible to the sun, may not receive its direct rays during a part of every day. We need not be forgetful of the bleaching and fading power of those rays, which lead the careful housekeeper to be afraid of them for her carpets. But, whatever compromise in the way of shades, blinds, or curtains, may be allowed, we should at least forbid, unless in the height of our American midsummer noon, the prison-like gloom of tightly-closed shutters. Even after a death in a house, it is a wrong to encourage gloom and invite disease by keeping the shutters closed, as some do, for many days together. Soon after the funeral they ought to be opened again. No child can grow strong and ruddy with the bloom of health, no invalid can respond favorably to the best of tonic treatment, in a constantly darkened house. Let the sun come in !

CHAPTER V.

WARMTH.

HARDLY anything has changed so much with the progress of artificial living as have the modes of warming habitations. Those of the ancients whose usages are best known, the Greeks and Romans, suffered from no such extremes of climate as compel protective arrangements in northern Europe and in the United States. A wealthy Roman might warm his banqueting-hall sufficiently with a *focus* or central fire, or a *clibanium* or brazier; something like which is now, or was, not long since, used for the Pope's apartments in the Vatican. In Spain, King Alphonso was once nearly suffocated by charcoal fumes from a brazier. Anticipation of our furnace-heaters was, however, evinced in the hypocaust, with which some of the Roman emperors warmed their palaces. This was a furnace with flues to distribute heat, but without a chimney, smoke escaping by a hole in the outer wall. It was subject to leakage; one emperor, Julian, was nearly, and another, Jovian, actually, suffocated in this way. In England, during

the middle ages, the fire, in the castles of noblemen, was moved to a deep recess against the wall, the smoke finding vent at a loop-hole in the roof, or by an open turret, or a louvre window at the side. Chimneys first came into use in Italy in the fourteenth century.

Water-stoves, it seems probable, were employed by the ancient Egyptians for hatching eggs; a process now common in that country. In modern Europe, they were introduced in France by the Marquis de Chavannes, during the last century. Hans Egede, a missionary writer, is said to have known of their use in a Dominican convent in Greenland, in the fourteenth century. Hot-water pipes were employed to heat a conservatory for plants, by Martin Triewald, a Swede, in 1716. For dwellings, these were brought into use in England about a century later.

Steam apparatus for warming began as an application of the boiler of the steam-engine. Watt so warmed his office, and his partner, Boulton, extended its employment in Birmingham.

Among the first inventors of stoves, properly so called, were Cardinal Polignac, Swedenborg, the visionary philosopher, and Doctor Benjamin Franklin. The stove of the latter was an open fireplace, brought out into the middle of the room, and having a supply of fresh air from beneath. It is approximated by the "Franklin stove" of to-day. Another celebrated American, Benjamin Thompson, Count Rumford, in-

troduced a fireplace system which is still much approved in England.

One of the remarkable modes of warming apartments, little known in this country, is the *kakelung* of Sweden. It is described as "a great stove of masonry, covered with porcelain plates, having usually five flues, through which the gases of combustion must pass up and down, a distance of thirty to fifty or even sixty feet, before escaping into the air." The principle of its operation is, to provide enough material to absorb all the heat from the fire; the gases being conducted through the long flues until they give up all their heat. If ventilation be well supplied by other means, this arrangement must be extremely economical, at least. In Germany and Russia, porcelain or brick stoves of a similar kind are still used, and are extremely comfortable.

The primitive blazing wood-fire, with logs heaped in the chimney-place, has everything in its favor in regard to beauty of appearance and freshness of the air. A backwoodsman's hut, with a fire on one side or in the middle, and a door wide open, will warm at least one side of each of its inmates at a time. The other side, exposed to the outer air, may be cold; so it may be needful to turn around, like a piece of meat on the spit, before the fire. This illustrates one, and the quickest and most effective, of the different modes of receiving communicated

heat, viz., by *radiation*. Nothing is equal to direct radiated heat in comfort and restorative power, when one has been chilled with winter's cold. But it is the least economical of all methods, as but little effect is felt in those parts of the room which are not in front of the fire, or nearly so. Moreover, according to the physical law of radiation, the heat diminishes in proportion to the square of the distance; so that at the distance of ten feet from the fire it is one hundred times less than at the distance of one foot.

Conduction through solid bodies, a very frequent mode of distribution of heat in Nature, has been made purposely available to only a small degree in warming rooms. By the walls of the house, however, heated by smoke, gas, and warm air passing up through chimneys and flues, rooms are considerably warmed. It is probable that the best way of all (scarcely anywhere as yet tried) may be hereafter found to be, to heat steadily all the floors and walls of apartments by warmed air circulating beneath and around or through them. This will give an evenly warm *climate*, so to speak, to the house; imitating the plan of Nature, according to which almost all the heat of the atmosphere of a region is given to it by the sun's rays heating the earth, which then communicates its warmth to the air. The Chinese have something like this, at least so far as providing warmth for their floors by slow fires underneath.

This last kind of conveyance of heat, by conduction, we follow, in part, in the use of stoves; which give their temperature to the air in contact with them. By expansion, warm air is made lighter, and so is displaced and forced upwards by the heavier cold air. Rising currents are thus caused, and a *circulation* of air results, as one can see by the curious undulating appearance of objects looked at over the top of a stove, as well as by the upward movement of light, floating particles above the heated surface. *Convection* is the technical term applied to this manner of diffusing heat.

When the fire by which air is warmed is in a cellar, basement, or hall, so that the warm air may be distributed, by flues and registers, into several apartments, we have the now common *furnace-heater*. It saves trouble and dirt—making one fire, out of sight, answer the purpose of as many as there are rooms to be warmed. But it is often unequal in the share of warmth given to the different apartments. If this difficulty be overcome by skilful and careful use of valves, dampers, etc., an important fact, often forgotten, remains, that while the cellar-heater furnishes warm air to *enter* the rooms, it affords, of itself, no *outlet* for its escape. There may thus be produced a pressure within a parlor or other room, so long as the doors and windows are shut, which is sometimes unpleasant and unwholesome. Again, when a door

is open, if there be no heat supplied in the entry or hall, a cold current creeps along the floor of the room, chilling the feet of those who are in it. In an apartment so warmed, there is often a difference of 12° to 20° Fah. in temperature between the floor and the height to which a man can reach. This is the reverse of what ought to be the case; since *to keep the head cool and the feet warm* is one of the most approved maxims of health. A room is only properly warmed when there is no considerable, if any, difference by the thermometer between the floor and the height of an ordinary mantelpiece.

What should the temperature be, say at the latter height, for health? Authors differ somewhat upon this point. A bright wood, or glowing anthracite or bituminous coal fire, will allow of a lower temperature of the air of a room than will suffice when there is no direct radiation of heat. Even the rays of the sun pass through the atmosphere without warming it, unless it contains floating vapors or solid particles. Yet we feel their warmth, often intensely, when they reach our bodies. A difference exists, moreover, according to whether we are sitting still, or moving about or working in any way. A workshop, gymnasium, or skating-rink may safely have a temperature many degrees lower than a drawing-room, sitting-room, lecture-room, or school-room. Only, when those who have been exercising actively

in a cool or cold apartment sit down to rest, they are in great danger of catching cold, unless they protect themselves immediately by some increase of clothing.

For a sitting-room of any kind, my own conviction is, that 70° Fah. at the height of a mantelpiece is the best temperature. Some writers, in England especially, have put it down at 68° , or even 65° . I believe such to be suitable only when open, radiating fires are employed. For a sick-chamber, 72° may sometimes be better, if the air can, by good ventilation, be kept fresh as well as warm. There is no necessary (although there is unhappily a frequent) connection between warmth and closeness of the atmosphere in a room. Of the harm done or endangered by over-heated rooms, an account is given in another volume of this series.*

Returning to the furnace-method of warming houses, a few conditions may be named as essential to its compatibility with health.

1. The furnace should be large in proportion to the house; so that with a moderate fire, not pushed, it may warm a sufficient supply of air to give a good temperature to the rooms depending upon it. A very hot furnace *bakes* the air, as it were, producing an unpleasant odor and an uncomfortable feeling through

* See *Winter and its Dangers*, by Hamilton Osgood, M. D.,
No. 5 of this Series.

the house. If the furnace be too small, it will not furnish enough heat, without driving the fire hard, in cold weather.

2. Air should be supplied to the air-chamber directly *from out of doors*. A cellar atmosphere, at the best, cannot be equal in quality to the open air, and at its worst may be very bad indeed. In another place we may farther allude to its evil possibilities.

3. Water should always be placed in the air-chamber, so as to evaporate constantly, and prevent undue dryness in the air of the house.

A certain amount of moisture in the atmosphere is essential to life itself. Every one is familiar with the destructive effects of the Simoom, Khamseen, and Harmattan winds of Arabia and Africa, which carry the scorching aridity of the desert with them, blasting everything that has life in their course. While excess of dampness is a very frequent promoter of disease, it is equally true that artificial heat, such as that of stoves and furnaces, tends to create the opposite extreme. Warming the air increases its capacity for retaining moisture without saturation. The term *relative humidity* is employed to indicate the condition of the air at any time and place, as compared with saturation. Calling saturation 100, for example, the relative humidity of the air may vary, in our climate, all the way down to 12 or less. Dr. Wetherill, some time since, found the mean of several

years at Washington to be a little over 68. At Halle, Germany, Müller found the mean to be 75. In Philadelphia, in twelve years, it was 68.5. Roscoe, in the House of Lords, in London, ascertained the range of agreeable humidity to be between 55 and 82; the mean between which extremes is 68.5. Best of all, no doubt, for health and comfort, is from 67 to 69.

Now, by raising the temperature of the air in any apartment from 50° to 70° Fah., its relative humidity may be reduced from 100 to 25; that is, from containing moisture enough for saturation down to one-fourth of that amount. Of course, then, there is reason for adding a sufficient quantity of vapor to bring it up to twice as much or more, say to 68. Dr. Wetherill estimated that the halls of Congress ought to have nearly eight gallons of water evaporated every hour for the proper hydration of their atmosphere. Prof. Joseph Henry, so long the admirable head of the Smithsonian Institution, introduced into its building an arrangement for adding *steam* to the air of the air-chamber of the furnace by which it is warmed.

From these examples, we may understand how important it must be to have an evaporator in every furnace air-chamber, and a shallow pan of water upon every stove used for warming our rooms.

4. Sedulous care must be taken that no leakage of gas occurs from any flue or pipe into the air-chamber.

Coal-gas is poisonous when concentrated. Not unfrequently, death has been produced by its insidious entrance into the air of occupied rooms. A telling instance was narrated, a few years ago, of what happened in a public school in one of our cities. The lady teacher, sitting at her desk on a raised platform, observed that some of her youngest pupils were nodding, and shortly several of them fell over on the floor. Bench after bench they were overcome, when her presence of mind sufficed to get the windows open, and to have the children carried to another room, where they revived. The cause of the trouble was, an obstructed and leaky stove-pipe, through which gas had been slowly escaping into the room and stealing their lives away, first acting upon the smaller scholars, breathing the air nearest to the floor. Many a time, without any such alarming immediate effects, gas from imperfect furnace flues in our city houses produces headaches, general discomfort, and debility, often ascribed to some other imaginary cause. It is quite necessary that the box or tube which admits air into the air-chamber shall be so tight that gas cannot be drawn into it when the upper door of the furnace is open. If the draught be imperfect, there may be, especially when fresh coal is put on, an escape of gas into the cellar. This possibility adds emphasis to the reasons for having

not the cellar, but the open air, to give the supply to the air-chamber for the house.

5. Warm air should be supplied to the main hall or entry with which parlors or sitting-rooms are connected; so that the doors of the latter may be open without causing currents of cold air along the floor.

6. Since, as above said, no *outlet* belongs to the warm-air system of itself, the needful air-movement must be maintained by some method of ventilation. Barker's arrangement of flues and registers for introduction and exit of air, so as to warm and ventilate at the same time, will be referred to on another page, under the head of Ventilation. Open doors, at all events, into the entry or hall, or open window cracks, must be insisted on, if nothing better can be obtained. Best of all, however, it will be, to combine the two modes of warming; by having an open-fire, for instance a "low-down" grate, in one part of a large room, or in one of two communicating rooms.

The open fire gives the glowing, comforting, radiant heat, and supplies ventilation by its upward draught into the chimney; while the air from the furnace air-chamber, if properly arranged, makes sure the diffusion of an equable and sufficient warmth through the house. Open-grate fires, burning either bituminous or anthracite coal or coke, are cheerful, and give out a great deal of heat. When the air for their draught is supplied from out of doors, entering

from the back or below, fire-ward currents along the floor are not produced. What is called, in England, the Galton system, has been found to work well also in this country — having fresh air introduced through a grating at the back into an air-chamber, and thence into the apartment above (or at the sides of) the fireplace. There is thus obtained a considerable economy of fuel. Ventilating stoves, upon a similar principle, are also employed. Among the arrangements which appear to have succeeded is the Ruttan “Air-Warmer;” and the editor of the *Popular Science Monthly** speaks in praise of what is called the “fire on the hearth.”

Objectionable, beyond other means of warming living-rooms, is the “air-tight” coal-stove. Yet, from their economy and convenience, stoves more or less nearly air-tight are very largely employed. If air is introduced into the room in good amount, and water is kept constantly evaporating upon the stove, an ordinary stove can be managed without necessary injury to health.

Cast-iron stoves are somewhat more permeable to gas than those made of wrought- or sheet-iron. Careful experimentation has shown, however, that no appreciable penetration of the metal (in the absence of cracks allowing leakage) by carbonic oxide or other gases takes place, unless at, or near, a red heat.

* November, 1879.

According to chemical authorities, cast-iron contains in itself more or less carbon, sulphur, phosphorus, and sometimes even arsenic; products of whose combustion may be given out at a very high temperature. No stove ought ever to be heated red hot in an occupied room. A stove large for the apartment is always the best, on account of its giving off sufficient heat with a moderate fire, instead of needing, from deficient size, to be constantly urged to a high heat.

In the homes of the poor, in large cities, from want of means to rent more than one, two, or three rooms for a family, a great evil in midsummer is, sometimes, the excessive heat of the cooking-stove. Near this, in a small room, often in a narrow, crowded court, the mother is obliged to lay her babe, and to watch the older children, while she cooks their meals or heats water to wash their clothing. No wonder that the "summer-complaint" attacks infants in such places; and no wonder that, when they are so attacked, medical skill often fails to bring relief, unless the little sufferers can be taken away to the open hill-sides of the country, or to the sea-shore. What a blessing of blessings to these is the sea-side "sanitarium" or the "country week"!

Large houses, even private dwellings, are not unfrequently warmed by pipes containing hot water or steam. Theoretically, hot water ought to be the best, from the hygienic standpoint; because the tempera-

ture produced by it, under ordinary pressure, is never very excessive, as that of steam may be.* Still, the positive and comparative usefulness and general advantages of both methods depend very much on the skill and care with which the apparatus is constructed and managed. It has happened to me to become well acquainted, during two years, with the disadvantages of an ill-constructed apparatus for steam-heat. Yet in many buildings it appears to give fair satisfaction.

It is of consequence to remember, at all events, that all pipe systems, yet more than warm-air furnaces, are absolutely without any arrangements for ventilation, which must therefore be otherwise supplied. Many authorities agree in recommending that, instead of having coils or lines of pipe as "radiators" in the different rooms to be warmed, the heat of pipes should be utilized by means of air-chambers, through which fresh air is passed in contact with them, and, after being warmed, is distributed through the house by means of flues.

Warming, as well as cooking, by means of gas, seems not unlikely to become common in our houses. It offers extreme convenience as its great attraction. Many years ago, I proposed, in a communication to

It is a singular mistake, made by some persons, to suppose that a room furnished by steam- or hot-water pipes is *moist*. As the pipes are always (if rightly made) entirely tight, water for evaporation is needed just as much with them as with ordinary warm-air furnaces.

the Franklin Institute, warming and cooking by means of pure hydrogen gas, conveyed through pipes separate from those of the gas used for illumination. It has the advantage of giving off much heat in proportion to its volume, and, what is more important, the product of its combustion is simple water; while ordinary burning gas produces also carbonic acid, carbonic oxide, and sulphurous acid, besides other deleterious substances contained in it before burning, which may escape through leakage. My proposition was set aside at the time, on account of the expense of the manufacture of hydrogen, compared with the cost of coal as fuel. Should coal become much more dear, or a very cheap process for making pure hydrogen be invented, the hydrogen stove may perhaps yet come into use. When common gas is burned, unless a special arrangement is made to carry away the results of its combustion, it vitiates the air considerably. A gas-stove needs a chimney, or at least an escape-pipe communicating with one, as truly, and for the same reason, as does a kitchen range or other stove.

It is, however, more easy to provide this in connection with a gas fire, on account of its being less bulky than one of coal; and the gas-burner's escape-tube or pipe may be made an excellent means of ventilation. Fassie* describes a plan for a gas-stove, in which fresh air is introduced by a pipe from the exterior into

* In his work on *Sanitary Arrangements, etc.*, before mentioned.

a cylinder which surrounds the burner; the latter being enclosed in, and receiving air through, a tube communicating with the outer atmosphere; the results of the combustion of the gas being carried off by the tube passing out above the stove. Thus there is no possibility of the air of the apartment being contaminated, and a good ventilation, as well as warming, is obtained.

The necessity of removing the products of the combustion of gas, as well as those from that of candles or oil, is very pressing. Prof. Pettenkofer ascertained that a man exhales every hour from six- to seven-tenths of a cubic foot of carbonic acid gas; saturation of the air of an apartment with which gas is fatal, and even four per cent. of it is dangerous to life. Angus Smith and Hartley assert that a good oil "moderator" lamp produces a little more than half a cubic foot, and a good candle three-tenths of a cubic foot of carbonic acid gas in an hour.

A common gas-burner, consuming three cubic feet of gas per hour, gives off about as much carbonic acid gas as three men would do in the same time.* Of course the larger size of the burners employed for warming or cooking purposes than for illumination must involve occasion for a proportionately increased supply of air in ventilation. Of this, however, we shall speak presently.

* Lange's estimate is, that a gas-burner giving a light equal to that of eight candles, produces nearly as much carbonic acid as six men.

CHAPTER VI.

VENTILATION.

ANCIENT Egypt, the site of the earliest civilization whose remains have been spared by time, appears to have been somewhat acquainted with the needs of ventilation. In the Pyramid of Cheops, probably older than Abraham, a passage exists, seeming to have had the purpose of conveying air into and out from the chamber in the interior of the structure. Acron, a Greek philosopher and physician, in the century before Hippocrates, is said to have arrested an epidemic at Athens by lighting fires in several places in the city to change the air. Celsus, the great Roman physician, alludes in his writings to the beneficial action of fire, the sun's heat, and elevated exposure, in purifying the air of sick-rooms. The ancient Romans sometimes employed great bellows for ventilation. In Germany, in the sixteenth century, bellows, and also rotary fans, were used to inject fresh air into, and force foul air out of, mines. Desaguliers imitated this in England in the eighteenth century; and also contrived a revolving fan to venti-

late the House of Commons, by drawing foul air out at the top of the building. This arrangement was in use for nearly eighty-four years. Dr. Hale, of London, during the same century, invented what he called "ships' lungs," for airing, by a kind of bellows, the holds and other parts of vessels at sea. Sutton, a London brewer, near the same time, attained a similar result by utilizing the cooking-fire on the ship's deck. Hospital ventilation, through aspiration by heated flues, was introduced into England by Sir George Paul, in 1820. Dr. Arnott, a little later, did a great deal to stimulate attention in Great Britain to ventilation. His chimney-place valve is still a good deal used. A curious but sensible proposal, made by Sir Humphrey Davy for the House of Lords, and afterwards carried out by Dr. Reid, was, to make a great number of "gimlet-hole" apertures for the removal of foul air.

No educated person denies the importance of ventilation; but scarcely one in a hundred of the best-educated people gives enough practical attention to it. It is proper, in this place, to go down to the elements of the subject. Why do we need to "ventilate" at all? Because we have to breathe; and, in breathing, we use up and spoil the air. Everybody knows what happens in drowning; air is, for a minute or two, kept out from the lungs by water, and the submerged person dies. So when a man goes into a

beer-vat, lately emptied of its liquid, but leaving some of the gas of fermentation, carbonic acid, behind, he falls over, and, unless at once rescued, loses his life. Sleeping in a room in which charcoal is burning, away from an open chimney, has, likewise, often been fatal. In these cases, it may be said, the air is poisoned. This is true ; but it is not more certainly, nor even so badly poisoned, as it is by human breaths and the exhalations of our bodies. Charcoal gas is carbonic acid ; we exhale that, and besides, with every breath, and from all the pores of the surface of the body, *deleterious organic matter*. This combination, when concentrated, will kill more quickly than the gas produced by simple combustion alone. In the famous instance of the "Black Hole of Calcutta," always cited in connection with this subject, one of the survivors of the night-long imprisonment (of one hundred and forty-six men in a room eighteen feet square) mentions, that although the room had in it two small windows, all but twenty-three men died ; several of them with different symptoms from those produced by breathing carbonic-acid gas alone. Another example of the same thing is the following : A steamer (the Londonderry) was overtaken in the Irish Sea by a storm. The passengers, about two hundred, having been ordered below, the captain, to prevent water from getting in, battened down the hatches. Before their suffering and alarm

compelled him to set them at liberty, seventy-two had died of suffocation. There is, then, *immediate* danger from want of ventilation. But this is far from all. An impure air may poison us slowly. Typhus fever (jail fever, camp fever, ship fever, of different places) may, I am well convinced, be engendered by this cause alone, as well as by contagion. Typhoid fever and diphtheria are, at least, much promoted by it; and, without any such diseases, a low state of health, with increased liability to scarlet-fever, measles, etc., and a greater probability of death when they occur, is a constant effect of close living. Pulmonary consumption, and other affections of the chest, as pneumonia and bronchitis, are much more common and more fatal with those who live all the time in ill-ventilated rooms, than in those who, with an active, out-of-doors life, are exposed to the vicissitudes and inclemencies of the weather. This is a fact which, if it were generally appreciated, might make a great difference in the manner of living of many people.

Air consists chiefly of two gases mixed together. Referring to larger works for more precise details, we may say that these are, about four-fifths of nitrogen and one-fifth oxygen. The latter is the vitalizing, indispensable principle; the nitrogen merely dilutes it. Also, the air contains a variable amount of watery vapor, which we cannot do without, but which may

be more or less disadvantageous by excess ; a quantity of carbonic acid, averaging, in the open air, three or four parts only in 10,000 ; and other ingredients, gaseous, vaporous, and even solid (dust, etc.), present or absent, according to locality and circumstances. Of these *non-essentials* of the atmosphere, the organic matter derived from human beings, other animals, and plants, living or dead, is the most important, because capable of doing the most harm by its decomposition and poisonous action.

A man, by his breath, will spoil, in twenty-four hours, about three hundred and fifty cubic feet of air ; as much, that is, as would be contained in a room a little more than seven feet square, with a ceiling seven feet high. Could all the carbonic acid gas exhaled by a man in that number of hours be collected, and its carbon extracted from it, the latter would be equal to half a pound or more of charcoal, besides the organic matter given off, whose amount is not easily estimated.

When people sleep in small rooms with closed windows and doors, or collect in numbers in church congregations, theatres, etc., with lights burning, and, in cold weather, with windows and doors shut to keep up warmth, foulness of the air is soon produced. Of this, an excess of carbonic acid is a part, and a sign of other impurity. If air contains more than six or seven parts of carbonic acid in 10,000, it must be counted

impure. Yet the following are amounts of that gas actually found by examination in certain localities:

	Parts in 10,000.
London school-room (Roscoe).....	29.
Munich school-room (Pettenkofer)	72.
Munich beer-saloon (Pettenkofer)	49.
Hospital, Madrid (Luna).....	43.
Bedroom, Madrid (Luna).....	48.
Lecture-room, Paris (Leblanc).....	67.

Diminution of the oxygen of the air occurs, also, from breathing and burning of fires and lights. If this goes so far as a loss of two or three parts of oxygen in a hundred, life is endangered from this cause, as well as from the negative or obstructive effect of excess of carbonic acid gas. This latter gas, when pure, cannot be breathed into the lungs; but when dilute, it enters them, and produces unconsciousness and death, more or less rapidly according to its amount. Where a lighted candle goes out, as in a beer-vat or an old dry well, or unventilated coal-mine, etc., it is known to be unsafe for a human being to go. Four per cent. of carbonic acid renders the air dangerous to life; ten per cent. will overcome any one almost immediately.

Considering, then, the propensity of many people for shutting everything up, the porosity of our walls, and the unintended cracks in doors and windows of most houses, must be regarded as fortunate and preservative. A movement of the air goes on by *diffu-*

sion, as well as by the winds and currents perceived by our senses. Pettenkofer devised a curious experiment to show how air penetrates through gravel. He half filled a glass cylinder with gravel, over which a wire netting was placed; on this a canary bird was put; over him another wire netting, and above that the cylinder was filled to the top with gravel. So the bird lives all day, without seeming to be incommoded for want of air. The warmth of its body induces a gentle ascending and descending current of air around it through the two layers of gravel, the upper one communicating with the atmosphere. Without such a movement to renew the air for it to breathe, it would be fatally poisoned in a very few hours. Although birds consume and require more air in proportion to their bulk than we do, yet our larger size involves a demand for atmospheric movement much greater than, without investigation, most people would suppose.



Fig. 2.

This demand is, too often, very imperfectly met. Look, for example, at the following figures, taken from good authorities. First, we must premise, that, as an adult consumes three hundred and fifty cubic

feet of air in respiration in twenty-four hours, *at least twice* that amount of space *ought* to be allotted to every person in a living apartment, whether awake or asleep. In a hospital, it ought not to be less than 1000 cubic feet for each patient.

	Cubic feet per head, allowed by regulation.
English Poor-Law Board, dormitories.....	300.
London Metropolitan Lodging-Houses.....	240.
London School Board, per scholar.....	130.
English Wooden Hut Barracks.....	400.
Prussian Barracks.....	495.
English Wooden Barrack Hospitals.....	600.

But cubic space does not settle the whole question, at all. Granting to each person in an unoccupied room 1000 cubic feet, the air in that space ought, for health, to be *all changed about four times in an hour*. Let us contrast, with the table above given, another, slightly modified from one calculated by Morin, an eminent French sanitarian.* It states the requirements which are now considered not too great, indeed quite moderate, for health:

	Air per head, per hour, cubic feet.
Hospitals for ordinary patients.....	2000 to 2500.
Hospitals for wounded or lying-in.....	3500.
Hospitals for epidemics.....	5000.
Workshops.....	2000 to 3500.
Public assembly rooms.....	2000.
School-rooms.....	1000.

* For the exact table, see Buck's *Hygiene and Public Health*. New York, 1879. Vol. I., p. 705.

But, say some of our readers, this is alarming. How can any ordinary house be provided with such a movement of air? It is, in fact, an easier matter than would, at first thought, be supposed. A good ordinary fire will cause from 6000 to 10,000 cubic feet of air per hour to enter and leave a room.* How are the winds caused, which sweep over everything on the surface of our earth? By differences of temperature, making the air heavier and lighter in different localities; the colder and heavier air moving so as to displace upwards the lighter warm air, and thus making currents in the atmosphere. The same cause is constantly acting in our houses, more or less powerfully. But it needs arrangement and encouragement to give it full effect.

Before saying more about this, it will be well to dwell upon another very important fact in Nature. It is remarkable that the proportion of the two gases, oxygen and nitrogen, of which the air is chiefly composed, is almost exactly the same everywhere, although they are only mixed, not chemically combined. From the "difficult air of the iced mountain top" to that which is filled with spray by the breakers at the margin of the sea, the same air is breathed by all, except where it is spoiled in or near human habitations or other artificial constructions. The "law," or general fact, of which this is an example, is the law of the

* *Healthy Houses*, by F. Jenkin, F. R. S.

mutual diffusion of gases. Every gas tends to expand and occupy all the space to which it has access; and different gases do not interfere with each other's liberty in this respect. Carbonic acid gas is so heavy that, when quite pure, it can be poured like water, from vessel to vessel; and yet, if a vessel of it is left open to the air, it will soon pass off and disappear. This is very important to us, as, otherwise, the amount of this heavy gas produced by all the respiration of men and animals, and the combustion of fuel, in our cities, would make the continuance of life impossible.*

This constant diffusion of air-constituents is not fully appreciated by all, even of those who have given attention to sanitary science. Some writers upon hospitals assert that the ceiling of a ward may be too high for good ventilation. I am sure this is a mistake. Familiarity with hospitals for several years, and comparison of them by visitation in Europe as well as in this country, besides what every traveller knows of the great cathedrals abroad, has confirmed to my judgment practically what should be expected according to theory, namely, that *the ceiling of no living-room, for the sick or the well, can be too high for health.* Of course, it requires more consumption

* A beneficent aid in the removal of carbonic acid from the air is provided by the action of the leaves of trees and other plants, which, during the daytime, absorb this gas, and give out oxygen in return. But this would not suffice without diffusion.

of fuel to warm sufficiently a room with a high ceiling than one with a low one ; but this is an economical rather than a sanitary question.

It is a maxim of pre-eminent importance, in regard both to breathing air and drinking water when exposed to causes of contamination, that *confinement and concentration intensify, while dilution and diffusion make innocent, most organic poisons*. To put the case strongly : I would rather, with a view to the safety of health, have a water-closet ventilated, even through a house, by open doors and windows communicating with it, than have it not ventilated at all, while used constantly. Indeed, the most terribly killing of all poisons of the kind now referred to is produced by shutting up old cesspools. Take, for example, such a case as this :

Not very long since, at Cleveland, Ohio, four deaths were caused by opening a cesspool, which had not been used for a number of months, and had been covered with planking, over which were eight inches of dirt. One of the men descended, in order to open it, into an adjoining privy vault, which was in use and ventilated. As soon as he made a communication with the cesspool, so as to allow its gas to escape, he fell over unconscious. Three others, who entered after him, experienced the same fate, and all died.*

* Report of Health Department, Cleveland, Ohio.

The question of drainage and "conservancy" will be considered later in this book ; but I wish to place here large emphasis upon this most vital difference between *concentrated* and *diffused* organic poisons of air or water.

It would be easy to bring together many instances of different kinds to illustrate the close relation of air-space and ventilation to health. I will here add but two, which are rather curious. The proprietor of a large factory in Manchester, England, having a working-room too small for those engaged in it, and not well ventilated, enlarged it. He was, soon after, obliged to increase the wages of his employees, because, with better air to breathe, their appetites became larger, and it cost them a good deal more to live. A dining-club, in Edinburgh, concluded that the ceiling of their dining-room was too low. They had it raised, and, in consequence, the amount of viands consumed at their prandial gatherings was found to be notably and expensively increased.

Yet, to show how singularly such simple sanitary principles may be misapprehended, a printed circular was distributed in Philadelphia by its Board of Health, in 1866, prior to an expected visitation of cholera, in which the families of the city were advised to shut up all their windows at four o'clock every afternoon, and keep them closed until ten o'clock the next morning ! This august body has, undoubtedly, gained

in wisdom by a dozen years of experience, or, with such ideas, it would not be a very safe guardian of the public welfare.

We may see, from what has been said, how obvious and simple are the objects to be aimed at in ventilation, however complicated and difficult sometimes may be their attainment from the interference of circumstances. These objects are :

1. To move uniformly through a building the required amount of pure, fresh air.
2. Duly to distribute this air to the different apartments in the house.
3. Properly to diffuse it in each room.
4. To remove the vitiated air from every room in the building.
5. To warm the air sufficiently in winter.
6. To supply it with an appropriate amount of moisture.

Most of the year, and for the majority of persons, it is necessary that the movement of the air through apartments in which they live should be gentle as well as uniform. That is, we must avoid draughts, unless in the warmest and driest of summer weather, when we court every breath of a zephyr, whose comings are "few and far between."* Yet there must

* At 60° Fah., air-movement is not felt as a draught unless it has a velocity of $2\frac{1}{2}$ feet in a second.

be a *movement through* every room, not merely one opening into it; outlets as well as inlets must be provided.* A chamber with but one window, with the door shut, and without either an open transom or a fireplace, is often insufficiently ventilated, except in windy weather. The best chance for such a room is to have the window open both at the top and at the bottom. The cold air will then enter below (being heavier), and the lighter warm air will escape at the upper opening. In order to get the most uniform air-movement through a room with the least draught, several inlets and outlets are always better than one or two. If there be two or more windows in a room, it is best to open *each a little*, both at the bottom and at the top. Thus the total of inlets and outlets may be greater than would be borne if a single window afforded it all, either at the top or at the bottom. It is wonderful *how small* the cracks may be which several windows will need to have as openings, in order to keep the atmosphere of a room sweet and pure.

Natural and *artificial* ventilation are often spoken of as two different and contrasted things. But, since all human constructions, houses included, are artificial, *spontaneous* or *accidental* would be a better

* In a private conservatory at Germantown, Philadelphia, last winter, every plant was killed in a single cold night, because, through oversight, although a warm-air flue opened into it, *no outlet* was left for the maintenance of air-movement through it.

term than natural. The other term, artificial, may as well be retained ; meaning the use of apparatus or special arrangements expressly for ventilation. By spontaneous or accidental ventilation, then, we mean, that of open fireplaces, doors, and windows. Of the fireplace, so serviceable even without a fire, a good deal has been said already. Windows and doors answer very well in a warm climate and in fair weather ; but they are uncertain and variable, and so liable to excess of draught, as to induce with many persons a constant dread of catching cold. Yet they may be managed, with care, so as to maintain a pure atmosphere within doors, even in mid-winter, so long as sufficient heat is afforded, by warming-apparatus, for comfort and health. They answer best, perhaps, with open fires. Many English sanitarians prefer "natural" ventilation to any other kind, for dwellings and hospitals. Among these, Florence Nightingale, one of the highest recent authorities on hospitals, exclaims against the "abominable artificial ventilation" of some European institutions.

Next to the purely spontaneous or accidental methods come those which, in a simple manner, add to or modify these. One such is the plan ascribed to Hinkes-Bird, which is described and figured in Dr. H. Osgood's *Winter and its Dangers*. It consists in the insertion of a piece of wood, made to fit under the lower sash of the window, raised a few inches.

Air then enters upwards, between the two sashes, at their place of junction. Still simpler, and equally effectual, is Dr. W. W. Keen's arrangement — placing,

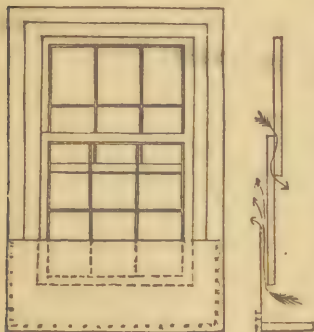


Fig. 3.

with tacks or pins (preferably the former, using loops of tape, which can be taken off and replaced, as wanted), a piece of cloth or paper across the lower ten or twelve inches of the window frame, and then raising the lower sash more or less, according to the weather.

Still another way of getting an upward-directed draught is by means of the Sherringham valve. For this, an opening is made through the wall, near the ceiling; and inside the room is a small shoot, or sloping board, closed in at the sides. A lid or valve, above this, may be used to lift or close, so as to regulate the amount of air admitted.

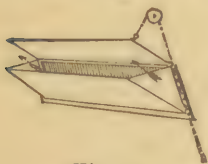


Fig. 4.

The same effect, however, almost exactly, can be obtained by fixing an upward-sloping board about six or eight inches below the top

of the window, and then letting down the upper sash a few inches.

An excellent method was in use, some years ago, in the temporary building occupied by the Episcopal Hospital of Philadelphia. A pane was removed from each of the windows in a ward, and in its place was introduced a piece of zinc, perforated with a number of small holes. Wire gauze will do about as well. This allows the air to come in slowly, without draught; and, moreover, it *tempers* it, by the conducting power of the metal, warmed by the heat of the room. The principle here is the same, essentially, as that of the Davy safety lamp for miners; viz., the rapid effect of short metallic tubes, or pores, communicating their own temperature to gas or air passing through them.

Nothing has pleased me more, after actual trial for a considerable time, than Maine's elbow-tube ventilator. This consists of a board (made in two parts, sliding on each other, so as to be adjusted to different windows), to be placed under a raised sash, as in Hinkes-Bird's plan, but having passed through it two pipes or tubes, about six inches in diameter, each bent upward in an elbow;

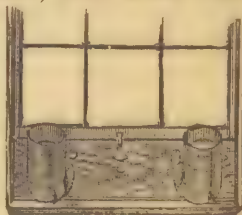


Fig. 5.

the top of each tube being open above, and supplied with a regulating valve.

By means of this arrangement, the cool air from out of doors is directed upwards altogether, and is not felt as a draught, even by those who sit quite near to the open ends of the tubes.

Inlets and outlets are both, as already said, necessary for due circulation of the air.* When they are made expressly for ventilation, the question occurs, Where shall they be? An opening in the wall, ceiling, or floor of a room may be either an inlet or an outlet, or both, according to circumstances. If it be connected with a flue from the air-chamber of a furnace, it will, of course, be, ordinarily, an inlet for warm air. If it communicate directly with the open air, it may be either an outlet for warm air, or an inlet for cold air. When there is an open fireplace in the room, it will generally be a cold-air inlet. In the absence of a fire-place, if there be a single opening, only, besides the warm air register.— this open-

* Dr. Parkes, in his *Treatise on Practical Hygiene*, says, that in a hospital, the sum of inlets and outlets should be not less than forty-eight square inches for each patient. Morin advises that the fresh-air inlet should equal fourteen square inches for every one hundred cubic feet of space. Whether inlets or outlets should be largest, sanitary authorities are not agreed. I am tempted to coin the word *throughlet* for an opening which may allow air either to enter or leave the room by it, according to the circumstances of temperature, pressure, etc.

ing will usually be an outlet, relieving the pressure caused by the furnace air-chamber flue.

A fireplace with a wide-throated chimney, and either a coal-grate or a wood fire burning in it, seldom needs any inlets or outlets for ventilation, besides the cracks which, unintentionally, exist in windows and door-ways. The chief problem concerns rooms warmed by heated air, or by steam or hot-water pipes. First, then, as to the warm-air arrangement. Several possibilities may be considered. Our diagrams may facilitate the comparison of them together.

In Fig. 6, warm air is represented as entering at I, near the floor, on one side of the room, and escaping immediately above this, near the ceiling, on the same side. A great waste of heat must result, with, no doubt, some, but far from perfect, ventilation.

Fig. 7 shows what will happen if warm air is admitted at the top of the room on one side, and allowed to escape also near the ceiling on the opposite side. Being lighter than the cold air of the room, the warm air will float over it, like oil over water, without affecting the room sensibly.

In Fig. 8 we have the inlet at the middle of the floor, and an outlet directly over this (above a gas chandelier, for example), in the midst of the ceiling. This will ventilate, but with too much loss of heat. Better, decidedly, indeed quite good, will be the arrangement shown in Fig. 9, in which two warm-air



Fig. 6.



Fig. 7.



Fig. 8.

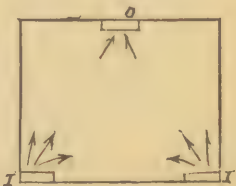


Fig. 9.

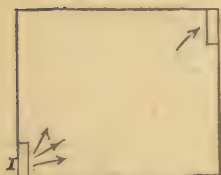


Fig. 10.



Fig. 11.

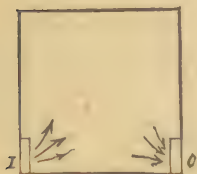


Fig. 12.



Fig. 13.

registers are placed, one on each side of the room, at the floor, the outlet being at the centre of the ceiling.

Fig. 10 illustrates the air-movement when the warm-air flue opens at the floor on one side, and the outlet is at the ceiling on the opposite side. This will give a good distribution of the air introduced before its escape through the outlet. In Fig. 11 this arrangement is reversed, warm air coming in at the ceiling on one side and going (or intended to go) out at the floor on the other side.

In Fig. 12 the inlet is at the floor on one side, and the outlet also at the floor on the opposite side. For this plan, or that of Fig. 11 to succeed well, there must be a *compulsory out-draught* to compel the warm air to descend from the ceiling to the floor and escape at the outlet. This compulsory draught can be afforded only in either of two ways: by an upward current determined by heat, or by mechanical aspiration, that is, the use of an exhausting pump or fan.

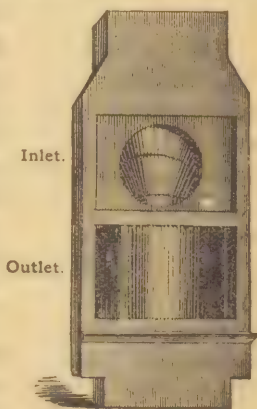


Fig. 14.

Figs. 13 and 14 are designed to represent the principle of G. R. Barker's warming and ventilating flue.

In it the warm air is introduced through a cowl-shaped inlet or register, elevated about a foot above the floor, while immediately beneath it is the outlet register, whose upward current is caused by the warmth of the metallic pipe through which the warm air is brought up from the air-chamber of the furnace in the cellar. Above this pipe and its cowl-like cover or top, and at its sides, the flue is open to the chimney. The course of air-movement, then, is this: warm air, entering by the upper register, rises, on account of its comparative lightness, and is distributed through the room; descending as it cools, it finds its way gradually to the floor, and then is drawn out by the lower register, where, being warmed by the exterior of the air-chamber pipe, it ascends to the chimney and passes out. This arrangement for warming and ventilation has been introduced successfully into the hospital of the University of Pennsylvania, in West Philadelphia. It appears to me the best, as it is one of the simplest, methods of ventilating apartments warmed by a furnace-heater.

Where an out-draught can be conveniently secured at an outlet near the floor, as in Fig. 12, the warm air entering on the opposite side of the room, also near the floor, an excellent effect is produced. But without such a provision for an upward current beyond the outlet (as by a pipe passing up through a chimney heated by a kitchen or other fire), cold air would often

enter instead, and the ventilation would be uncertain and imperfect.

For private houses, simplicity and convenience will usually decide in favor of an arrangement such as is represented above in Figures 9 and 10; the latter, particularly, in rooms not very large, where a warm-air register, at the floor on one side, or at one end of the apartment, and a ventilating outlet, near the ceiling, on the other side, or at the other end, will give a very good distribution of air. When the door of the room is open, instead of warmed air escaping, cold air may enter the room at the opening near the ceiling; but that, if moderate in amount, is not objectionable; as a *circulation of air*, with sufficient warmth, is what is always wanted in ventilation.

How much air can be safely admitted into a sleeping- or living-room, is a common question. Rather, it should be considered, how *rapidly* air can be admitted, without injury or risk, and at *how low a temperature*. We cannot have too much fresh air, so long as we are warm enough, and are not exposed to draughts. What is a draught? It is a swift current of air, at a temperature lower than the body, which robs either the whole body, or an exposed part, of its heat, so rapidly as to disturb the equilibrium of our circulation, and give us cold. Young and healthy persons can habituate themselves to sleeping in even a strong draught, as from an open window, if they

cover themselves, in cold weather, with an abundance of bedclothes. But those who have been long accustomed to being sheltered from the outer air by sleeping in warmed and nearly or quite shut-up rooms, are too susceptible to cold to bear a direct draught of cold air. Persons over seventy years of age, moreover, with lower vitality than in their youth, will not bear a low temperature, even in the air they breathe. Like hot-house plants, they may be killed by a winter-night's chill, and must be protected by warmth at all times. As a rule, we may say, that, except for the most robust, the air which enters at night into a sleeping-chamber should, in cold weather, be admitted gradually only, by cracks or moderate openings; or should have its force broken by some interposed obstacle, as a curtain, etc., to avert its blowing immediately upon a sleeper in his bed. The ancient fashion, however, of having *bed-curtains*, which exclude almost all the air, has rightly become almost obsolete. No wonder that people dream horrid dreams, and wake in the morning wearied rather than refreshed, when they sleep in rooms sealed up tightly on every side; breathing over and over again their own breaths, which grow more poisonous with every hour of the night.

Many different systems and apparatus for ventilation of rooms and houses have been invented, more or less ingenious and successful in attaining their end

—Muir's, McKinnell's, Tobin's, Ruttan's, Hulin's, and a host of others. For these, we must refer the reader to larger treatises. Our aim has been to set forth, as simply as possible, principles which may be applied and adapted to various circumstances. As already said, those who use open fires instead of stoves, furnace-heaters, steam- or hot-water pipes, may be congratulated as not requiring, usually, any special arrangements to supplement the action of their own chimney-places. If, as some estimate, so much as nine-tenths of the heat of an open-grate fire goes up the chimney and is lost, it is, at least, not wasted, since it does excellent work in providing what every one needs, but almost no one values aright: good ventilation.

CHAPTER VII.

WATER SUPPLY.

THIRST is more terrible than hunger. Nearly three-fourths of our bodies consist of water ; and we part with a large amount of it, constantly, in different modes, including exhalation of a pint or two, daily, in our breaths. We must, therefore, have a constant renewal of it. Half an ounce, daily, for each pound of our weight, is the average need of an adult ; but some of this may be taken in soft solid food, as bread, vegetables, and meat. Adding what is necessary for cooking and cleansing purposes, from fifteen to thirty gallons, daily, will not be too much of a supply to provide for each person in a household or community. As a *minimum*, may be mentioned the allotment on a man-of-war—one gallon, daily, for each man. If travellers' accounts are true, the water supply of the city of Munich is, or has been, even less than this. Since the natural humidity of our Western hemisphere is greater than that of the Old World, it is, in most places, easier with us than in Europe to obtain an ample supply of good, wholesome

water; so that the excuse of "bad water," for indulging in less advisable drinks, does not exist among us.*

The *quality* of water is of great importance. Its kinds are (besides that which is artificially distilled), *rain, melted ice or snow, spring, well, river, lake, marsh, and sea-water.* The last named (sea-water) is quite undrinkable; it will not quench thirst, but nauseates and causes distress. Marsh-water is almost always decidedly unwholesome. Yet that of the Dismal Swamp, on the borders of Virginia and North Carolina, is reported to be very good, and is in demand for sea voyages, on account of its keeping so well. When water runs out on board of vessels at sea, distillation is often resorted to to make sea-water available for drinking and cooking.

It might be imagined that the most desirable of all waters would be that which is distilled, leaving behind all dissolved solid ingredients. But that is not so; distilled water is insipid and less agreeable, without being more wholesome, than many natural waters. The fact is, that the substances contained in ordinary good spring- or river-water are very nearly

* There is, it is true, a region in our Western country, that of the "alkali flats," where the surface water is not drinkable. Even there, probably, at some future time, driven or Artesian wells may procure a supply of good water; although this, of course, is uncertain before trial.

the same as the mineral constituents of healthy human blood. We instinctively prefer a water which has some taste, and this quality is promoted even by the presence of absorbed air, commonly present in it.

Rain-water is not at all identical with distilled water, even when it is collected *directly* from the air. It contains washings of the atmosphere, different according to locality. In the country, besides oxygen and nitrogen of the atmosphere, and carbonic acid, there will be in it a little of some other gases (as sulphuretted hydrogen from organic decay) and *dust*, which consists of mineral, vegetable, and animal particles of various kinds. Over a city, rain as it falls gathers more impurity; among other things, sulphurous and sulphuric acids from combustion of coal and other fuel, ammonia, and other results of the decay of organic matter of every kind. From the roofs of houses, over which it usually flows before it is collected, rain also washes a certain amount of the excrement of birds, etc. This can be avoided if the first portion that falls be allowed to escape; which, however, is not always easy to attend to in time, where rain-water is systematically accumulated for use.

Rain-water is not to be preferred to other waters when they can be had in abundance and of good quality. But, under some circumstances, it is the best and most wholesome water that can be obtained. For example, the city of Venice, built upon a hun-

dred islands in the Adriatic Sea, has been for a very long period supplied by rain-water, collected in filtering cisterns underground. Filtration should always be employed when rain-water is used for drinking and cooking. It is less necessary, of course, when it is employed (as, on account of its softness, it very frequently is) only for washing purposes.

At one of the New Jersey watering-places, a few years ago, there occurred a number of cases of typhoid fever. All those attacked were residing in houses supplied by driven wells from the ground-water; all those who used rain-water for drinking and cooking escaped. This eminently illustrates one of the cases in which the clouds will furnish the only safe supply, the alternative being the drawing of water from a porous, sandy soil, into which is permeating all the filth of human habitations, from soil-wells, kitchen drains, and stables. Of this, however, more hereafter.

Enough rain-water can be collected in most places for family use, with filtration. A house forty feet by twenty, with a rainfall like that of the vicinity of Philadelphia (from forty-two to forty-five inches annually), will furnish from its roof an average through the year of sixty gallons daily. It may be collected in a tank near the roof, or in an underground cistern. The latter will be, on the whole, the most satisfactory. The best material for such storage is slate.

Iron, coated with coal-tar paint to prevent rusting, will do; or brick-work, lined with cement. Lead, or even zinc, ought never to be used for a tank or cistern. Rain-water will dissolve enough lead to be certainly poisonous, and enough zinc to be at least possibly injurious. Every such cistern should be covered, to keep out rats, mice (in the country, squirrels), birds' excrements, etc. A strong but close iron wire cover over part of the cistern will have the advantage of allowing air to reach the water, while protecting it from contamination. Such will not be advantageous, however, unless the air around it be devoid of impurity. Certain cellars are sources of great insalubrity, having in them refuse of all sorts, decaying remains of vegetable and animal food, grease and filth of every kind; and all this without sunshine and fresh air from out of doors to purify them even in a slight degree. Water stored in such a place will be, however covered, in danger of generating or promoting typhoid fever, diphtheria, cholera infantum, or some other mortal disease. Bad air and bad water are the two most potent *removable* or *preventable* agencies concerned in inflicting these maladies upon humanity.

Every cistern, moreover, should be cleaned out regularly, at intervals varying somewhat according to their size and amount of use. Once in three months will never be too often for this.

Other things being equal, flowing water will always be the best. Stagnation allows of the accumulation of the results of decomposition; movement and mingling with the air break up, dilute, and dissipate them. No beverage is better or more wholesome than good spring water. It is rain- or snow-water which, falling from the skies on some mountain or other elevated land, runs through earth and rocks, dissolving mineral matter as it goes, until, at some lower place, it gushes forth, clear and sparkling, to the air. Some springs have their waters so charged with saline or gaseous constituents that they are called *mineral springs*; carbonic acid, sulphur, and iron, with salts of magnesia, etc., being among their most common and important ingredients.

Springs coming from a moderate depth in the earth are pleasantly cool. They have about the average temperature of their locality for the year. Yellow Springs, in Pennsylvania, have a temperature of about 52° Far., which is the mean of Philadelphia for a term of years. Some other springs, from great depths, are warm or hot, even boiling; as the geysers of Iceland, Montana, Wyoming, and California.

A country house is fortunate if it possesses, at a convenient distance, a good, cool, copious spring. Nothing is more attractive or more serviceable about a Pennsylvania farm than the spring-house; often jutting out from a bank or hillside, built low, but firmly,

of gray stone, and shaded over by a few old trees. Within, you see the clear, transparent pool of water, in its reservoir of stone, pure as the air or sky overhead; and around it, or carefully placed in it, the pans of milk or cream, or butter, waiting for family use. A draught from that supply, flowing out to make a limpid stream through the meadow below, gives more refreshment, on a midsummer day, than the most tempting beverage of man's contrivance. It has in it no horrors, no mockery, *only health*.

Well-water is like spring-water in many respects, but is not nearly always identical with it. Being detained, for a time at least, instead of flowing freely, it may become contaminated in many ways. Authors now refer constantly to the *ground-water* of a region as important in regard to water supply and influence upon the air. Wells are made by digging down to this, at a greater or less distance below the surface of the earth.

Two sources of supply exist for the ground-water itself. One is the local rainfall, penetrating directly through the earth; the other is the flow or soakage from neighboring regions. If the soil be sandy, or in any way loose and porous, rain-water and melting snow will be diffused through it, sinking till they reach clay, hard rock, or some other layer of resisting material. Such a supply will vary with the weather and the season, and may be exhausted by use at any time.

There are shallow wells in some places which, having almost no other dependence, show nearly every year this unreliable character. Most wells, however, receive their water from the general ground-water, which is continuously and slowly moving through an extended region towards a river or lake, which is the line or centre of drainage of the country. Alongside of a river or lake, or even but a few yards from the seashore, in not a few places, wells have been found to furnish water considerably different from that of the sea, lake, or river—the underground movement being *to*, not *from*, those great natural reservoirs.

An important difference in the quality of well (or spring) water is its “hardness” or softness. Hard water does not easily make lather with soap. The reason is, that the “salts” which it contains, especially those of lime (or its metal, calcium), yield bases which make, with the fatty acids of soap, insoluble compounds; while none such are formed with any ingredients in rain or other soft waters. Two kinds of hardness exist—removable and permanent. The former consists chiefly in an excess of calcium (lime) carbonate, dissolved by aid of carbonic acid in the water. The latter depends upon the presence of calcium sulphate in excess.

Three ways are resorted to for removing the first of these kinds of hardness. One, the simplest, is by boiling the water. This drives off the excess of carbonic

acid which has kept the calcium carbonate (as a bicarbonate) dissolved. It is then thrown down as a deposit, from which the water may be poured or strained away. Another method is the common use of "washing soda," sodium carbonate, which combines with the carbonic acid, making a sodium bicarbonate. This also causes the excess of calcium carbonate to be "precipitated" from the water. The third method is the addition of quicklime, in suitable amount, to the water. This, like the soda, unites with the excess of carbonic acid, and throws down the carbonate of calcium, which was dissolved by its aid, in the water. All these plans act alike in ridding the water of the carbonic acid in excess, which keeps the superfluous calcium carbonate in solution. Without either of them, an abundance of soap will overcome the effect of hardness, although wastefully as regards expense.

Such, however, are questions of convenience, rather than of health. Is hard water more, or less, wholesome than soft water, as a drink? One English authority, Dr. Letheby, has endeavored to show that it is more favorable to health. Others dispute the inference from his facts. It is, indeed, difficult to separate the influence of drinking-water from other modes of local causation. It appears to be almost certain that cattle pastured upon a limestone region grow larger-boned than those upon alluvial grounds.

Even men show some difference, in their average stature, in such regions. Nevertheless, an excess of calcium and magnesium sulphates (the latter being "Epsom salt") is sometimes present to a sufficient amount to produce irritation of the bowels, and diarrhoea, in persons accustomed to soft water. Travelers and new-comers often suffer this inconvenience,* while residents habituated to it are not at all affected by it. A reason why soft waters are not unfrequently charged with insalubrity, is, that they flow through, or are used in, low regions, in or near cities, where impurities of various kinds get access to them. On the whole, our preference may safely attach to a *moderately* hard water; although soft water, in a locality free from all contamination, is unobjectionable. It is quite supposable that those who drink rain-water only, may lack a sufficient supply of mineral matter for growth and repair of the substance of the bones. Yet, so much of all the mineral substances needful for building up our skeleton, and the other tissues of the body, exists in our articles of solid food, vegetable and animal, that we can hardly regard this as likely to be important. At all events, for it to be so, there must be a general deficiency of mineral elements in the soil of the locality from which plants are grown,

* For this, the best corrective is *essence of ginger*, five or ten drops in a tumblerful of hard water.

and on which animals are fed, as well as in the water.*

Wells differ much in the nature of their water, according to their depth. Usually, the deeper well drains a larger extent of country. Much depends, however, on the character of the ground, its slopes, and elevation or depression, as compared with the surrounding region, as well as on the nature of the rocks underneath. *Driven* wells may be shallow or deep. They are made by forcing through the ground a wrought-iron tube, having a valved piston at its upper part, and at its lower end a steel point. Above this point, for some distance, the pipe (which is usually an inch and a quarter to two inches in diameter) is pierced with holes, for the admission of water. In many places where no water at all appears upon the surface, a few feet of penetration will reach it and bring it up, sometimes even in abundance. Thus artificial *oases* have been made, as way-stations of refreshment for travellers, in some portions of the great African desert. It seems not impossible that, in the future, the desert may, by irrigation from such wells, be made actually to "blossom as the rose."

Artesian wells are essentially of this character; only

* I have often thought of the question, to solve which facts are wanting, whether *early decay of the teeth* is not most common where only soft waters are drunk.

this name is applied to driven wells of great depth. They are said to have been used, ages ago, in China and Egypt. Now, many of them exist in Europe and America; some, one, two, or three thousand and more feet in depth. They are uncertain of success, unless the selection of locality be guided by geological knowledge. One at Grenelle, Paris, eighteen hundred feet deep, yields a large supply for local use. The deepest one in this country, at St. Louis (Asylum well), 3843 feet, has been a practical failure, after costing more than \$10,000. Lately, it is stated that some brewers in New York city have been able to obtain, at one hundred and fifty feet depth, a thousand gallons a minute, through a pipe of six and one-half-inch bore.* This water is said to have a temperature of fifty-two degrees Fah. At greater depths, the water is much warmer. That of the Grenelle well is 80.6° Fah. One at Louisville, Kentucky, 2086 feet in depth, has a temperature of 76.5° Fah.† This is a great objection, except where, as in our cities, ice may be employed to correct it. A considerable excess of mineral matter is a more serious drawback to the use of water from very deep wells. That of St. Louis, above mentioned, is unavailable, chiefly for this reason. Yet a great advantage of very

* *Sanitary Engineer*, November 15, 1879.

† A well recently completed near Buda-Pesth, Hungary, 3200 feet deep, is said to yield water at 165° Fah.

deep well-water is, its almost certain freedom from organic matter resulting from animal and vegetable decay. This kind of matter often pollutes shallow well-water — most of all in cities. Pump-water in cities ought never to be drunk at all, no matter how clear and bright may be its appearance, or how agreeable its taste. *Color and taste are not decisive of the quality of drinking-water.*

Well-water in the country is often tainted badly by the well for the household supply being too near the privy or the barn-yard. It may be seriously injured, even, by the draining into it of kitchen waste. Thirty feet should be the *least* distance ever to be allowed between a privy and a drinking-well.* Sixty feet will be better; and the slope of the ground is also important. A privy should always be located *below* (if there be a slope) the house and its well. In choosing a site for a house, we should look out for the distance and direction of our neighbors' drainage as well as our own, and carefully avoid having to receive that of other houses on its downward course.

* The editor of this series informs me that he knows of a case, in a town in New York State, where a cistern was placed with its wall but three feet from the privy-well, its sides only plastered, and that not on brick, but directly on the earth. Continued sickness in the family, and one death from typhoid fever, caused an examination of the cistern, revealing the above facts, and a direct stream of drainage from the privy-well into the cistern.

Wells are sometimes liable to a less damaging, and yet considerable inconvenience, from the roots of trees.* At my residence, near Haverford College, a few years ago, an old willow tree sent out its roots to a deep well twenty feet distant from it. When discovered, the root-fibres were actually filling the well, so that, on looking into it, one could see only the roots, no water being visible at all. Elm-trees, and some others, have been known to do the same thing. The only cure for such an invasion is, to cut down the over-thirsty tree.

Of the danger of injury to health from polluted wells, it is hardly possible to say too much. In one cholera season in London, six hundred deaths were traced to the use of a single street pump. Typhoid fever has been repeatedly, indeed many times, known to affect whole families who resorted to a well for a common supply, while others in the same neighborhood, using different water, were not attacked. Worse yet, perhaps, seems to be the subtlety with which organic poison may be conveyed, by water, through *milk*, in dairymen's supplies. Several times this has happened in London, and elsewhere in England. In one instance, so far as appeared, the only mode of contamination was by the milk-pans at the dairy being washed in water from a stream into which leakage

* Roots are also sometimes sent into cracks of leaky drain-pipes or sewers, which may thus be obstructed.

had occurred from a neighboring privy. At another time, several well-to-do families in London, one of them that of a physician, were affected with typhoid fever. It was found that they were all supplied with milk by a company which furnished milk from several dairies. At last it was ascertained that cases of fever occurred only in those families to whom had been sent the milk of one particular dairy; and a local cause of contamination of its supply was also traced. What exquisite cleanliness of all things is enjoined by this experience! Nothing is more sensitive than milk and cream to all impurity. Even the water which cows drink, when marshy and bad, has been known to make their milk unwholesome. Butter can be made good only where the most scrupulous sweetness, cleanliness, and freshness of everything is maintained. This is the chief secret of good butter-making; and the "moral of it" may be extended and applied by saying, that perfect cleanliness of water, food, air, and person is, everywhere, absolutely necessary to perfect health.

Streams and rivers furnish, the world over, to the greater number of mankind their drinking-water. They have the advantages of copiousness, facility of access, and movement, which favors agitation with the air and freshness. But they are liable to contamination on account of their exposure to solid and liquid refuse and waste of all kinds. Worst, for this

danger, are small, shallow, slow streams, running through or by towns or villages, or near factories, graveyards, slaughter-houses, etc. River-water is best when taken from the largest, deepest, and most rapidly flowing river, *near its middle*, and a few feet below its surface.

Turbidity in river-water makes it look uninviting, but does not always affect its wholesomeness. Opacity is due almost entirely to suspended mineral matters, and they may be quite innocent.

With all its solid material, giving cloudiness and taste, the water of the Mississippi, for example, is drunk by very many persons, and has been found to keep well at sea.

Those accustomed to such a water often consider common river- or well-water too insipid to be agreeable. Marsh-water, however, as already said, is generally quite unwholesome, promoting especially diarrhoea and dysentery.

Lake-water taken from a large lake, far out, has all the good qualities of river-water, and is less often exposed to contamination. A small lake, or pond, if so exposed, has, on account of its actual or comparative stagnation, less opportunity of purification than a flowing river.

Organic matter constitutes the really serious impurity of streams and rivers. Worst of all is excretory material, sewage, from human habitations.

Next to this, drainage from slaughter-houses, bone-boiling, fat-rendering, and soap-making establishments, etc. Dye-stuffs may color water a great deal, without a proportionately injurious effect, unless arsenic or copper be present in them. Vegetable impurity of all kinds is less deleterious than that originating in animal decomposition. One grain of organic matter per gallon, chemists assure us, is all that a first-class drinking-water ought to contain; yet some pleasant and apparently innocent waters contain as much as ten grains in a gallon. One test is, adding a lump of white sugar to a vial of the water, and keeping it corked for a few days. If it contain much organic matter, it will become, in that time, perceptibly turbid. Another sign of this kind of impurity in water is its acquiring an unpleasant smell when corked in a bottle and kept in a tolerably warm place (say at 70° Fah.) for three or four days.

Rivers have some power of *self-purification*, or else those which, near large cities, receive sewage and also furnish drinking-water, would be still more destructive to life than they are. This evil is, it is true, so great as to receive at present much attention from sanitarians. The means of this spontaneous purification are chiefly *deposit*, *oxidation*, and *diffusion*. By deposit, solid particles are thrown down, making the water clearer. Oxidation, under exposure to the air, does much more than this. Oxygen acts chemically upon

organic impurity, breaking it up into its elements, and destroying all its noxiousness in course of time. How long this requires, it is difficult to determine exactly in any case. Dilution and diffusion accomplish the most beneficial results in natural water purification. With a sufficient mass of water, everything soluble, or capable of suspension in the form of minute particles, will be divided so infinitesimally as to become utterly harmless. The magnitude of this effect is shown, for example, in the river Merrimac, Mass., which receives all the sewage of the manufacturing towns, Lawrence and Lowell; and yet it has been computed that to increase the amount of its solid matter below Lawrence, so much as one grain per gallon, would require the addition daily of one hundred tons of dry material to the river.*

Yet, since the poison-causes of human diseases are very subtle (whether they consist of "disease-germs" or not), what we know of the morbid transporting power of water should make us very cautious about using water for drinking or cooking into which any drainage or sewage from human habitations or establishments can ever enter. Cities and smaller communities will never reach the ideal pointed out by sanitary science, until all their sewage is, in some

* W. R. Nichols, in Buck's *Hygiene and Public Health*; also, *Report of Mass. State Board of Health*, 1874.

manner, removed, daily or constantly, and returned to the earth for use in fertilization. The manner in which this is done in China and Japan, where those who bring produce from the country to sell in the markets of the towns, return laden with house-soil to manure their gardens and fields, seems to us rough and not æsthetic. But their *idea* herein is quite correct. It remains for our knowledge and invention to solve the problem in some better and more agreeable way. No one has written more eloquently about this than Victor Hugo, in his chapter on the Sewers of Paris, in *Les Misérables*.

Some organic material on the surface of rivers and lakes is innocuous while in the living state. Over many ponds and along the edges of some rivers, may be seen quantities of green scum, consisting of confervoid growths, algæ, minute cryptogamous (*i. e.*, not flowering) plants, of various species. Probably the growth of these vegetations is, in itself, advantageous to the water, by using up material resulting from other decomposition. But when the same organisms die and decay, as they will do especially when the margin of the pond or stream recedes with drought, then their decay becomes a cause of contamination. This is still by no means the worst kind of water-spoiling. It was, in 1876, very noticeable for a time in the Croton water supplied to New York city, giving the water an unpleasant odor and appearance.

Yet this was a transient occurrence, and no considerable sickness was ascribed to it. A green scum on a water-surface may be regarded as having its principal importance in its being a sign of stagnation, which is always unfavorable to the good quality of a water supply.

Melted snow and ice must be here briefly spoken of as sources of drinking-water. Snow, like rain, carries down whatever the air contains. Over towns, it will, therefore, contain a little ammonia and organic matter. Since a low temperature arrests decomposition, there is not apt to be much injury result from the latter in snow. In one way, however, snow-water has been known to become injurious. In Finland and Northern Russia it has been common for people to throw out near their houses all the refuse of their daily living, and then, in the winter, to collect snow from the same ground and use it for drinking and cooking. This has been believed to aid in explaining the lingering of epidemic cholera, in some years, in those countries in the winter, while elsewhere it disappeared at or before the end of summer.

Water, in freezing, parts with most of the ingredients suspended or dissolved in it. Ice is therefore purer than the water from which it has been congealed. This, along with the already-mentioned influence of cold in arresting chemical decomposition, makes the risk of unwholesomeness in melted ice very small.

Yet, a few instances are on record of injury to health resulting from the use of ice taken from foul water. This can only happen when the supply is obtained from a shallow, stagnant marsh or pond, where animal or vegetable decay has been going on. Such ice will be apt to exhibit its character by lack of clearness and transparency. The deeper the water from which ice is gathered for use, of course, the better.

Much importance attaches to the *mode of conveyance* of drinking-water from wells, reservoirs, or other sources of supply. Lead, iron, and tin are the materials most employed for this purpose.

The great convenience of lead pipes causes them to be very largely resorted to for carrying water. Certain facts concerning them ought to be generally known. Distilled water and rain-water will dissolve enough lead from pipes to make them poisonous; so also will very soft well-water, and even that of some streams. It requires but one-tenth of a grain of lead, per gallon, to affect very susceptible people with lead-colic, or even lead-palsy. When Louis Philippe, ex-king of France, was residing with his family at Claremont, England, some of them were injured by lead dissolved in the water of a reservoir. I have known of two instances in which the same thing has happened in this country. Even the drippings of evaporated water, condensing on a leaden cover over a tank, have sometimes contained enough lead to do harm. Cro-

ton water, in New York, according to Professor Chandler,* always has traces of lead in it, but not enough to produce any effect, unless when the water is drunk after having lain long in the pipes. Fairmount water, at Philadelphia, is perfectly safe in this respect.

Everybody should know that this security is due to a very simple action of the water on the pipes. River-water, and that of some, but not of all, wells, contains saline ingredients, which, being partially decomposed, make a deposit, lining the pipe with a delicate crust, and thus protecting it from further action. Rain-water, and that of certain wells, having an insufficiency of such constituents, dissolve the lead to a considerable extent, and thus become injurious. *Hot* water may do the same, even with Croton or Schuylkill water. Some cooks have a bad habit of saving themselves trouble in heating water for cooking on the fire, by using that of the kitchen-range boiler. Besides the not improbable construction of the boiler with copper, of which hot water will dissolve enough to do harm, the action of heated water on the leaden pipes makes such water altogether unfit and unsafe to use.

Lead pipes had better never be employed to carry rain-water, or that from wells, at least unless that of the last has, in every instance, been shown by chemical analysis to be safe. If there be doubt in this

* *Sanitarian*, May, 1875.

regard, a wise precaution is always to allow the water to run for awhile, and empty the pipes, before using it for drinking or cooking. Incidentally, it may be mentioned that water containing carbonic acid (soda water, mineral water) dissolves a good deal of lead; and therefore pipes made of it should never be employed for soda-water fountains.

Iron pipes are acted upon by hot water, their rust sometimes being in sufficient excess to be disagreeable. Cold water may be passed through either cast- or wrought-iron pipes without any disadvantage. Galvanized (zincd) iron has been shown to be acted upon to some extent, a little zinc being dissolved when water lies long in the pipes. Some chemists assert this to be enough to make the water unwholesome; but authorities differ upon this point. No doubt, allowing the water to run from such pipes for a few minutes before using it, will prevent any injurious effect, as the soluble compounds of zinc are much less poisonous to the human system than those of lead.

Block-tin pipes are as free from objection as any others. Tin-lined lead pipes are good so long as the lining lasts; but this is not forever. Two metals, in contact with each other, are more easily acted upon (as all experiments with galvanism show) than either metal would be alone. Therefore the lining must be thick and even, to be depended upon. The same is true of the "enamel" lining of iron pipes—made

usually by dipping them in coal-tar or some form of cement. Glass-lined iron pipes were patented a few years ago, and have received approval from the editor of the *Manufacturer and Builder*, and from the consulting sanitary architect of the Board of Health of New York. These are so prepared as to avoid bursting from freezing, an inconvenience of which we see much in this country. To prevent this accident, care must be taken in the *placing* of lead pipes, as well as in having them made of the proper thickness and strength. If a pipe is necessarily exposed to cold, the water in it is much less likely to freeze, or to burst if it does so, when the spigot is so turned that it drops a little all the time—thus providing space for the expansion which water always undergoes in freezing. Wrapping an exposed pipe with flannel (or strips of old carpet), through the cold weather, may save a great deal of trouble of this kind.

Of all things, care must be taken not to allow a water supply for drinking to be exposed to impurity, from the overflow or waste-pipe of a cistern being connected immediately with a drain. It is very important, also, for the same reason, to have *different* reservoirs (if such are used) for drinking and for water-closet use. Of these matters, more will be said in our next chapter.

What can be done to *purify* water for drinking,

when the use of that which is of imperfect or uncertain quality cannot be avoided?

Nothing is more effectual in annulling the injurious influence of contaminated water (in the absence, that is, of a mineral poison, such as arsenic, copper, or lead) than *boiling* it before use. Many a time it has happened that, when bad water has produced a local "endemic" of typhoid fever, all those affected have been drinking the water cold, while those who only took it in the form of tea or coffee have escaped. This was the case, for example, at St. Mary's Hall, Burlington, N. J., in 1875, when, as related by Dr. Leconte, thirty cases of typhoid fever occurred within two weeks from contamination of the drinking reservoir, by leakage from a privy vault. None of the servants of the house, who drank only tea and coffee, and almost never cold water, were attacked; while the boarders, often thirsty, drank cold water freely between meals, and all the cases were among them.

Filtration is often very serviceable, upon a large as well as a small scale. We are here concerned only with the latter. Most nations have practised this from the earliest times. On the Nile, travellers now have the yellow water of the river strained clear through the sides of the *goolch*, a jar or pitcher made of a porous clay peculiar to Egypt. Similar to this is the *alcarazza*, for a long time in use for the same purpose in Spain. A filter largely used in the British

navy is made of a very porous kind of Maltese rock. We imitate nature profitably, in filtering water through sand and gravel. These, with animal charcoal, make probably the best possible filtering materials. Sponge is also used; for wholesomeness it must be changed frequently, or at least scalded and well washed. This, indeed, is true of any filter. Without frequent cleansing, the pores become clogged, and instead of purifying, an accumulation of filth may make the water worse than it was. When charcoal is employed, it may be renewed by heating it strongly (short of combustion) in the open air.

The action of charcoal and sand in filtration is of two kinds. Partly, it is mechanical — *straining* the water, that is, keeping back solid matters by simple resistance. Besides this there is a chemical influence exerted, chiefly by oxygen of the air brought into very close contact with the particles of the water and its contents in the fine porosities of the filtering substance. This close contact is beautifully exemplified in the philosophical lamp, in which a jet of hydrogen is directed upon a piece of spongy platinum, within whose meshes it takes fire from the molecular action of atmospheric oxygen.

Iron, and some of its ores, especially in the spongy state, exert a purifying influence upon unclean water. Two such preparations have of late years met with considerable favor; *magnetic carbide*, and a new arti-

ficial mineral, recently employed in England, called *carferal*.*

Of the various patent filters on sale for household use, it may be said that, while several of them produce tolerable results, none are perfectly satisfactory. Unless themselves carefully cleansed or renewed at not very long intervals, they lose their cleansing power. For domestic use, I would rather trust to a *home-made* filter like that proposed by Dr. Parkes.† Take a large common flower-pot and put into it a bit of zinc gauze or a clean bit of flannel, then coarse gravel to the depth of about three inches, over that the same amount of white sand washed very clean, and, next, four inches of charcoal in small fragments; animal charcoal when it can be had. On the top of all, a piece of well-cleaned sponge may be placed, making sure that this is changed or thoroughly cleansed once in a week or two; more or less often, according to the impurity of the water. But really suspicious water should, before using it for drinking or cooking, be boiled as well as filtered. Above all, in regard to drinking-water, the great thing is to choose and provide for every household a supply which cannot be suspected. Here, as much as anywhere, is the maxim true, which lies at the basis of all hygiene; that *prevention is better than cure*.

* London *Medical Times and Gazette*, October 11, 1879.

† *Treatise on Practical Hygiene*.

CHAPTER VIII.

DRAINAGE.

“OURS,” says a late writer on house construction, “is the Age of Plumbing.” Egyptian, Greek, and Mediæval architectures have, each in succession, had their day, and now the beautiful gives way, in a large degree, to the useful. Stramm, a German author, declares that the highest modern civilization is shown not so much by costly monuments and works of art as by the perfection of house conveniences. Yet these, too, have their dangers as well as their comforts. Security does not always come with refinement. Ferocious beasts and venomous serpents are kept at a distance in the wilderness; but the subtle poison of disease may steal upon us in our beds, and, vampire-like, draw out the life from our veins. When the Prince of Wales, some years ago, fell ill with typhoid fever after a visit at Londesborough House, all the world was alarmed. It is probable, however, that the inquiry which this event, and its supposed cause, started, may have resulted in saving many lives.

When a house is being built for occupation in a

chosen situation, its light, warmth, ventilation, and water supply having all been provided for, there remains the question of conservancy; that is, the safe and sufficient removal of all waste. In the country, simple measures will answer, so far as health is concerned. On an acre of ground, there is space enough to place a privy at a good distance both from the house and from the drinking-well. If there be any slope, the last-named must be always above the first, and thirty feet *at least* (the more the better) must intervene between the two wells. Kitchen slops should have their own separate drainage, or, at least, should run through a channel, *open* for a short distance, before they enter the privy-well.

But it is a question, with a cottage or small farmhouse, whether a *well* for necessary waste is best. The farther from the house it is possible to place it, the less need there is of a well. The common cottage privy above ground, the building being raised and open (below) at the rear for frequent removal, needs only a simple precaution to make it innocent. This safeguard is, to throw over the deposit each time a small shovelful of lime or dry earth. The latter is, of course, the more accessible, and will deodorize and disinfect perfectly, if enough be used. A pint and a half in bulk, or two and a half pounds in weight, will suffice each time. A box of earth and a trowel may be left within reach. Frequent removal is then

important. Where there is a vegetable garden, the material thus accumulated makes the best possible manure. This has been proven not only in China, but in Europe and in this country also. With a small family, however, when dry earth is used, once in three or four weeks will commonly answer for its removal.

There are two sides to the question of advantage to health in regard to the distance of a privy from a country house. Delicate persons run risks in the exposure of going out of doors in cold or rainy weather. A covered passage-way, with windows, or otherwise open at the sides for ventilation, lessens but does not entirely obviate this evil. For those who cannot or ought not to leave the house, a convenience is needed. Much evidence favors the *earth-closet* as here the best resort. There are different patterns of this, but the idea in all is the same. By a mechanical contrivance, each time that the closet is used, a suitable amount of dry earth or sifted ashes is thrown down from a receptacle in which it has been placed. Those who cannot afford to buy an earth-closet can substitute it by keeping within reach a small box supplied with earth and a trowel for its use. The disadvantage of this is the flying of dust into the room; which, indeed, the best contrived closets do not always entirely prevent. Especially with the addition of a very little chloride of lime in powder to the earth when used, or even without this, an earth-closet is much more

satisfactory than the old-fashioned chair in the sick-room, or elsewhere in the house, for the avoidance of everything unpleasant.

Earth for this purpose must contain some (but not too much) clay and some *humus*, or soil such as is fitted for cultivation. Common garden earth, or that of the average farm ground, will do very well. Sand will not answer. Sifted coal-ashes will, almost as well as earth. On a small scale, earth may be dried in any convenient receptacle over or near the kitchen fire. For a large family, a quantity of earth may be placed to dry gradually under a shed, with boards under it to keep it from the dampness of the ground.

The earth-closet system has been introduced into several towns in Europe with success. But the requirement of bringing a great weight of earth into a city, and economically disposing of it after use, will make it slow to take the place of the water system in cities. Household employment of the latter system, therefore, must next receive our attention.

Every kitchen should have its drain, as it is against all laws of health, as well as of appearance and comfort, to throw slops out of doors on the ground. Garbage in cities is, or ought to be, removed daily in covered carts from all houses. In the country, a good plan is to *dry* hard materials (potato-skins, etc.) *under* the kitchen fire, and then *burn* them *upon* it. Otherwise, such things may be given to hogs, or dried at a

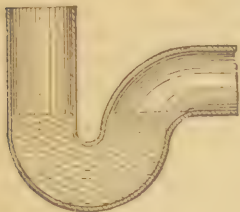
distance from the house and burned. Dust swept from floors may be thrown into the fire. Liquids from the kitchen must not be poured upon the ground near a well, or they will run or soak down into it and spoil the water. I remember once seeing, upon drinking-water, taken from an excellent well, a film, which broke easily into pearly particles, the origin of which nobody knew. The drainage was supposed to be all right. Chemical examination proved the film to consist of soap; and close inspection showed that an unnoticed obstruction had caused the kitchen drain to send a good portion of its contents right down into the well. This could be soon corrected. But sometimes a *foul* kitchen-drain taints a drinking-well for a long time without suspicion, doing very serious harm. Sanitarians aver that kitchen drainage *may* become almost as bad as sewage from house and street waste.

Every kitchen-drain, therefore, should have a *trap*.* Since this is true, also, of every water-closet, we may now at once consider what traps are, and what is their use. They are intended to prevent foul air from getting back to a house from sewage or drainage, after the latter has been discharged.

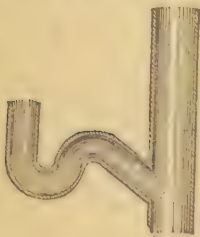
A *water-seal* is afforded, as shown in the figures (Figs. 15 and 16), by the portion of water detained

* A grease-trap, arranged for easy and frequent cleansing, is an important addition, at least in a large establishment.

after a quantity has passed through the pipe. Conditions necessary for the security of every trap are: that it be large enough; the "drown" or dip of

**Fig. 15.****Fig. 16.**

water above the upper line of depression, at the middle, sufficient; that this dip be not lost by distortion of the pipe (see Fig. 17, correct, and Fig. 18, dis-

**Fig. 17.****Fig. 18.**

torted); that it be of material thick enough not to be soon corroded and perforated by sewer air or water; that it be not clogged by solid and insoluble things

thrown into it; that it be furnished with an abundance of water for "flushing," or cleaning it out frequently; that it be ventilated; and that, when not used, it be not allowed to become dry from evaporation. All these conditions are frequently violated or neglected; and hence some people have come to regard all traps as entitled to their name in a contrary sense, as snares or delusions. But when properly made and used, they are very serviceable; and, whatever farther advance sanitary science and invention may hereafter furnish, we cannot, so long as we employ the "water system," do without them now.

Cast-lead traps are generally used, of good weight, seven or eight pounds of lead for each square foot of surface. A trap for a soil-pipe four inches in diameter should have the same diameter, and should weigh twenty pounds. The "drown" or depth of water above the upper bend should be, for such a trap, at least an inch and a half. To prevent swagging down out of shape, every pipe, through its whole length, trap and all, must be securely *fastened* and *supported*. Nothing should ever be thrown into a water-closet or sink which cannot be soon softened and dissolved away, so as not to produce obstruction. Every trap should have its own water-cistern, *distinct* from any cistern supplying drinking-water; and the flow through it when used should be free and abundant. Its overflow-pipe should discharge apart from

any sewage drain. The time when evaporation is likely to dry up traps, so as to permit the entrance of air from the drain or sewer below, is when families are absent from their homes, as during the summer season, or when a house is for any reason unoccupied for weeks or months together.

Bell-traps (see Fig. 19), according to the best authorities, ought never to be used, on account of their

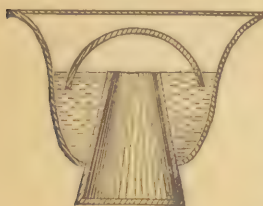


Fig. 19.

clogging more easily than other traps, and always allowing only a sluggish flow through them. Since all traps necessarily delay the movement of the contents of pipes, and stagnation makes everything worse, it may be asked, Why is it

not better to avoid all such interruptions, and merely provide such abundant flushing as will sweep all impurity rapidly away? The answer is, that if such thorough and constant flushing were secure in the *whole length* of every drain and sewer of a connected system, no traps would be needful. As such thoroughness is not usually, if anywhere, obtainable, "water-seals" limit, to great advantage, the amount of exposure of the air above them to contamination.

It has been proved by experiment that sewer-gas is *absorbed* by the water of a trap, if it remains long

there at rest, and then the gas is given out above and beyond the water-seal. Therefore, frequent changing of the water is indispensable; and, also, measures for making sewer-air itself as innocuous as possible.*

Ventilation of traps is of much importance. In considering it, we must look at the general arrangement needed for good house drainage, taking a somewhat summary view of the whole matter.

A house with "modern conveniences" has occasion for pipes (besides gas-pipes for light and warm-air flues) for the following purposes: 1. To introduce water for drinking, cooking, washing, bathing, and water-closet uses; 2. to carry off the overflow from drinking- and washing-hydrants, and from cisterns for water-closet supply; 3. removal of kitchen and other slops; 4. water-closet drainage; 5. ventilation, so far as required, of the above arrangements.

Of reservoirs and pipes for water supply, it needs only to be repeated here that the same tank or cistern ought never (even if divided by a partition) to be used to furnish water both for drinking and for water-closet use. Moreover, the *overflow* pipe of a drinking-tank or cistern must be carefully kept clear of the soil-pipe drain and sewer. It is best for such overflow, as well as that from every "lavatory" or wash-

* All sanitarians agree that *fresh* sewage is nearly harmless to the atmosphere. It becomes more and more deleterious, according to the time of its concentration and stagnation.

basin, to discharge by itself. In the country this may fall into a surface or sub-surface drain, at any convenient place at the rear or side of the house. If, in a city, *all* drainage *has* to be united at last, effort should be made to have drinking and washing overflows to fall upon an open (or at least well ventilated) catchpit or gully, leaving an interval, which if open may be covered by a grating, before it enters the common drain. Bath-water may take the same course as the above, leaving, when possible, some interval between the places of discharge.

Kitchen drainage is subject to greater foulness than water from drinking-hydrants, lavatories, or baths. In a *perfect* system, it must be kept apart from them in its conduction and discharge. It ought much more urgently to be separated from the water-closet drainage. This last needs, for really good sanitation, to be *entirely apart* from all the other drainage of the house.

We have, in this scheme, *at least three* desirably separate systems of discharge: A, that of drinking and other cistern or basin *overflows*, and bath water; B, that of the kitchen sink and other slop-wastes of no worse character; and C, that of the water-closets. The more completely these three can be maintained in separation from each other the better. Next best, in entire mutual isolation, will be the junction of A and B, with their conduction and discharge distinct from C.

When this last exclusion *cannot* be effected, we must look to traps and ventilation for the best practical means of protection. A plan of the plumbing of a house so guarded has a formidable appearance; and yet the dangers are so real, that we cannot easily estimate the expense and trouble which are worth while, in order to guard ourselves, our families, and our neighbors against them.

If, then, the overflow-pipe under a drinking-hydrant, lavatory, or bath-tub must, in any case, discharge into a drain which receives also the kitchen slops, or worse, the contents of the soil-pipe from water-closets, a trap must be interposed to prevent the ascent of foul air into the apartments concerned. For lavatories, Bower's trap (Fig. 20) has been found to answer well; best when it is all made of zinc or lead, instead of partly glass.* B, in the figure, represents a floating ball of rubber, which, being buoyed up by the water in the trap, makes a doubly efficient seal against the ascent of impure air to the lavatory from the drain below.



Fig. 20.

* The unequal expansion and contraction of glass and metal under changes of heat and cold (especially when hot water is used) make their connections somewhat insecure against leakage.

In passing, it may be observed that *every house which has two or more rooms on a floor ought to have a bath.* Hellyer proposes that in humble houses it should be placed *in the kitchen.* Although this seems odd at first thought, yet it is not unreasonable. It secures warmth for both the water and the air without trouble, and the bath-tub can be covered with a hinged board, making it a convenient bench at ordinary times.

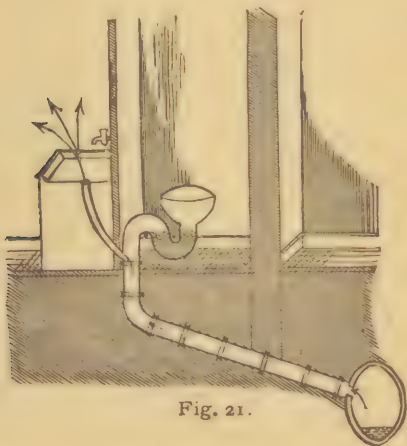


Fig. 21.

Every bath waste-pipe, also, when it connects with a soil-pipe, house-drain, or sewer, should have a trap; such, for example, as is shown in Fig. 15 or Fig. 16. So, also, must every kitchen-sink, and slop-sink of

any kind, have the same protection. Otherwise, there is opportunity for bad air to rise through those pipes, and to contaminate the air, food, and water in the kitchen or elsewhere through the house. How this may happen is easily seen by looking at Fig. 21. There the water-closet has been trapped, but not the kitchen-sink, and both communicate with a sewer.

Not only the sink itself, or lavatory, or both, but in each instance, as already said, the *overflow also* must be protected by the trap. Figs. 22 and 23 (borrowed from Teale's *Dangers to Health*) exhibit, respectively, the fault here indicated, and its remedies. These remedies (Fig. 23) are: first, making the overflow-pipe enter that of the sink *above* the trap; and secondly, having the lavatory escape-pipe to discharge over an open channel, instead of

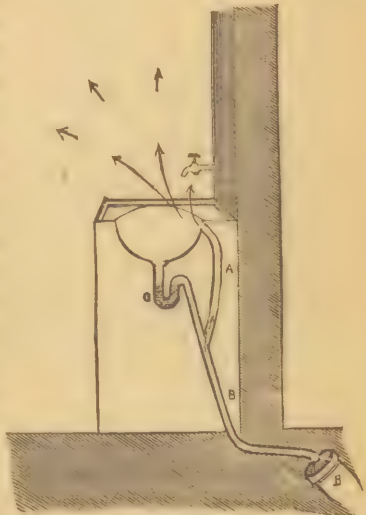


Fig. 22.

connecting *directly* with a soil-pipe or sewer. The first of these measures of protection can always be had; the second should be, whenever it is practicable.

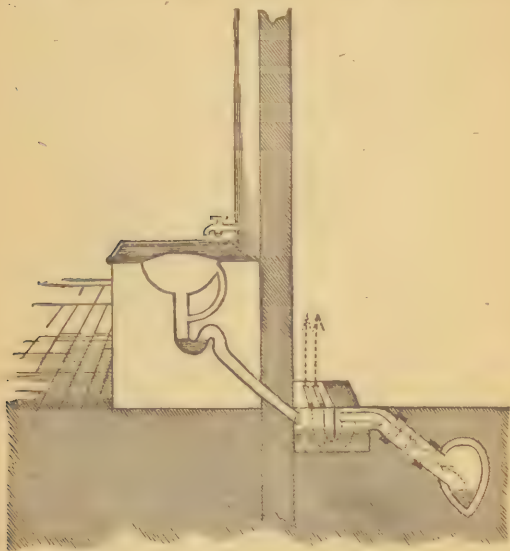


Fig. 23.

Now, for the most serious part of the problem before us, we must consider water-closet and soil-pipe arrangements.

The water-closets most in use are of two kinds, *pan* and *valve* closets. The former has an iron "con-

tainer " below the basin or receiver. This iron vessel is hard to keep clean. In the valve-closet, a portion of water is detained above the valve, which is quite an advantage; and there is no large container. The valve-closet is decidedly the best, but also the most expensive. Simplicity is so desirable in such fixtures (as, indeed, in everything else) that good authorities are inclining towards a return to the oldest form of the "hopper" immediately over the trap. Waring, the most esteemed American authority, has lately* asserted his preference for such a plan. Fig. 24 gives a view of Rhoads' Cistern and Hopper Closet, which carries out this idea very well. So also does Hellyer's Short Artisan Hopper (Fig. 25). Of other closets, more complicated, I believe Hellyer's valve-closet to be one of the best.

Whatever form or plan of water-closet be used, it is of great importance to provide an *abundance of water* for flushing it. Mere dribbling will not suffice. Neglected water-closets left to

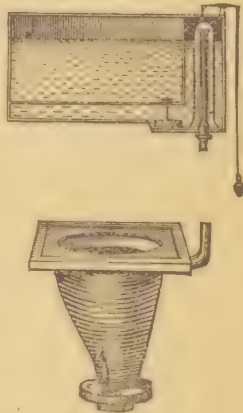


Fig. 24.

* *Atlantic Monthly*, July, 1879.

accumulate obstructive materials of any kind, will, in time, grow very foul, sometimes even worse than the average open privy.

Soil-pipes are now mostly made of iron.* *Enameled*



Fig. 25.

iron is the best material, with caulked lead joints.

Four inches will be not too large for a house of moderate size; four and a half or five inches diameter will be enough for the largest mansion

or hotel. All sanitary engineers now agree that it is a serious mistake to make drain-pipes too large. A drain six inches in diameter will suffice for more than a hundred houses. In a large pipe, but partially filled, the flow must be sluggish. The same amount of material in a smaller pipe nearly full, will move rapidly through it, and thus avoid stagnation. For changes of direction, and entrance of branches, right angles must be avoided, and as few inclined joints should be made as possible. Figs. 26 (right) and 27 (wrong)† will illustrate this principle.

Every soil-pipe should have a trap at or near its

* Among good authorities, Hellyer is almost the only one who still prefers thick cast-lead for soil-pipes. See his *Dulce Domum*, London, 1877, p. 29.

† From Ough's *Hints on House Drainage*, London, 1879.

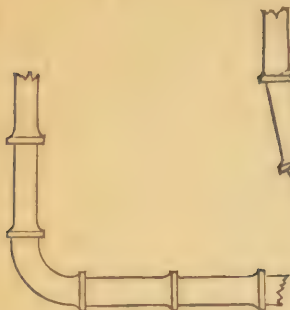


Fig. 26.



Fig. 27.

junction with the drain or sewer into which it discharges. It is well also for this to be aided by a flap-valve, to assist mechanically in the exclusion of sewer-air.* Some late authors recommend *two* traps in this position. Such a trap, or traps, should, when possible, be outside of the house, and accessible for inspection. This accessibility, it may be here remarked, should be provided for in the construction

* Waring, in a late article (*Atlantic Monthly*, July, 1879) advises the addition of mechanical arrangements to all water-seals. Such, however, are very apt to get out of order and disappoint expectations. Where storm-water is excluded from sewers, and they are ventilated, Waring (*Sanitarian*, December, 1879, p. 533) approves of the *omission* of the trap at the foot of the soil-pipe. This principle is now carried out in the drainage system at West Point; but it does not appear to be **safe with ordinary city sewers.**

of *all drains and drainage-pipes whatever*. A plan of the house-plumbing and drainage should be made when it is built, and kept for reference at any time. The absence of such a plan may sometimes cause great inconvenience and damage. In a house known to me, rented out by an owner who was absent in Europe, the need of such a plan was strikingly shown. An odor near the centre of the house gave rise to re-

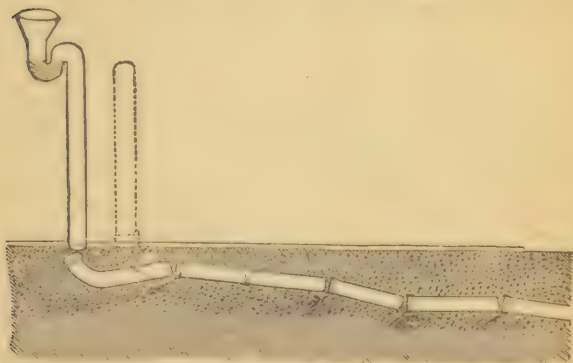


Fig. 28.

peated investigations without much result, until a carpenter, led by other similar experiences, took up part of a chamber floor, under which was found a pipe designed to ventilate a privy just at the rear of the house. This pipe passed into the kitchen chimney; one of its joints had become leaky, and gave out

foul air immediately under the floor of the chamber, making it uninhabitable until the fault was remedied.

House-drains running under or upon the ground should be made of salt-glazed earthenware. It is better for them to be made of iron, and suspended from the lowest floor. If on the ground, they should be laid with great care, upon a bed of concrete, or at least with good "clay puddling," and the joints secured with the best cement. Sinking of the ground under a drain, unless effectually provided against, may result in broken joints, with leaking of sewage under or near the house, saturating the ground in the most injurious manner. No drain should ever run *under* a house when this can at all be avoided.

Next, *ventilation* must be supplied for all the house-drainage system. This is needed, first, for each trap; secondly, for the soil-pipe; thirdly, for the drain or sewer into which all the house-drains empty.

Every trap should be ventilated from the *top* of its *outer* bend. Its vent should not go into the soil-pipe or its ventilating-pipe, but should have a separate air-pipe. All the traps of the house, however, belonging to baths, lavatories, and cistern overflows, may be vented by branches connected with the same pipe, if this be quite disconnected with the water-closet system. The only satisfactory way to ventilate a soil-pipe is to *continue it* all the way up above the roof;

best, to a height of ten or twelve feet above the eaves, and always in a direction clear of all windows. Rain-water pipes must not be used to ventilate soil-pipes or drains. When connected with these, they are of no use in this way during storms, and, at other times, opening just at the eaves, they may, when so connected, take bad air into upper windows.

Some have recommended an *open* trap (covered by a grating) for ventilation at the foot of the soil-pipe. (See Fig. 29.) Better than this is an air-pipe, which need not be more than two inches in diameter, *ascending* from the trap at the foot of the soil-

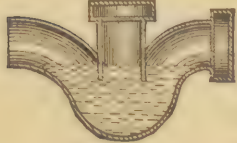


Fig. 29.

pipe to or above the highest part of the roof. This U-shaped arrangement of soil-pipe and foot-ventilating-pipe together has been found to work extremely well. The foot-pipe may answer for receiving all the water-closet trap-ventilators of the house. A patent has lately been taken out for the use of a ventilating-pipe for water-closets apart from the soil-pipe; but there is excellent reason for believing this patent to be invalid.*

For additional air-protection, a small vent may pass

* Hellyer's *Dulce Domum* advised this plan very clearly in 1877. See the *Sanitary Engineer*, Nov. 15, 1879.

from the water-closet immediately *under the seat*. This must *not* enter the soil-pipe or its ventilator, but it may quite safely be led into and carried up through the flue of the kitchen chimney. Ventilation of a soil-pipe directly into the kitchen chimney is sometimes arranged for, but it is not advisable. Downward draughts (particularly when, for a time, the fire is out) may mingle impure air from the soil-pipe with that of the kitchen. If the ventilating-pipe goes *through* the flue and up *the whole height of the chimney*, there is no considerable risk of



Fig. 30.

harm. As a rule, however, no pipe containing foul air should be allowed to go *through* a house when it is possible for it to ascend or descend *outside* of the house. The chance of leaky joints within a house is too serious to be permitted when avoidable. If there be such a pipe carried through a house, it ought to be of metal (preferably enameled iron), not of earthenware, or worst of all, of wood. Arrangements intended to promote a healthy state of things may sometimes, through unskilfulness or negligence, have the very opposite effect. At Sandringham Palace, a residence of the Prince of Wales, a mistake was com-

mitted of this sort. The vent of a water-closet, under the seat, above the trap, was made to enter the soil-pipe, thus giving full opportunity for the air from the latter to return into the open basin of the closet and the room around it. This error is shown in Fig. 31. The plan exhibited in Fig. 30, of ventilating a bath-escape trap and a water-closet trap by the same pipe, is not perfect; although it is much better than some methods in common use.



Fig. 31.

Experience shows it to be unwise ever to have a water-closet immediately communicating with a bed-chamber. The length of time spent in sleep, often without much renewal of the air, and, it seems probable, a greater susceptibility than in the waking state to depressing causes, makes the danger of blood poisoning greater under such than under any other circumstances, if contamination of the air exists. When a water-closet is not well supplied with window-ventilation, this may be supplemented, or in part substituted, by a pipe going upward through the roof, under whose expanded lower opening a small jet of gas is kept constantly burning.*

* The topic of *downward* ventilation of water-closets and latrines, by adjoining heated air-shafts, belongs to *Hospital Hygiene*.

So far, we have considered the ventilation of traps and soil-pipes only in view of their air-purification. But there is another occasion for it. When two or more traps, one over another, connect with the same soil-pipe, the discharge from an upper one may, in passing downwards, suck (or "syphon") out the water which seals a lower one, and thus leave it empty. This, of course, allows the ascent of foul air, passing the lower trap; and such a possibility is not at all a matter of theory merely, but of frequent, actual occurrence. When air is admitted not only through the open end of the soil-pipe, but also by a vent above each trap, such a syphoning and unsealing cannot occur.

Supposing, then, that we have arranged to convey safely out of a house all its drainage: what are we to do with it?

First, in towns. Privy-wells ought never to be considered allowable, even in closely built villages, much less in populous cities. They cannot often — certainly they cannot generally — reach to flowing water, or to an entirely pervious sandy bottom. Therefore they will gradually saturate the earth, contaminating the "ground-water," and, in consequence, more and more, the ground-air. One fact in regard to air-movement we have not yet alluded to; namely, that, in all but the warmest months of the year, the *whole* of an inhabited house, and, *through* the year,

that part heated by the kitchen fire, is, on account of its warmth being greater than that of out-of-doors air, drawing, sucking in air from the surface of the ground, and from the ground itself, around it.

Thus "sewer-air" (which, properly speaking, means all air spoiled by human waste) finds access to houses whose interior arrangements are, in themselves, without fault.

If this be true, so long as the earth-closet system, or nightly removal by a *pail* system (both very good, but not yet made convenient for large communities in this country) cannot be maintained, we have no resort but connection with the common sewer. Opposition to this has grown out of numerous cases of harm done by the escape of sewer-air into houses through defective plumbing. But no bad plumbing should be allowed ;* and the air of the largest sewers may be kept innocuous by proper construction, good slope, ample water supply, and ventilation. We cannot enter, in this volume, upon the topic of city sewerage ; but it may be said, at least, that the old style of immense square-built, brick sewers is an abomination which ought now nowhere to be tolerated. If made round,

* Municipal inspection of all houses when built, and afterwards when reasonable complaint occurs, is one of the needs of our great cities. Tenement houses in New York are now subject to it ; and surely the rich ought to have at least *as much* protection as the poor.

or egg-shaped (with the small end downward), of a size not large enough for stagnation, and of impermeable material, properly cemented at the joints, they will need then only abundant flushing and numerous air-vents to make them safe throughout. In Croydon, England, the first construction of sewers was followed by an increase of typhoid fever; but after the sewers were well ventilated, the disease disappeared almost altogether. Yet the connection of house-drains with town-sewers must be very carefully guarded: the

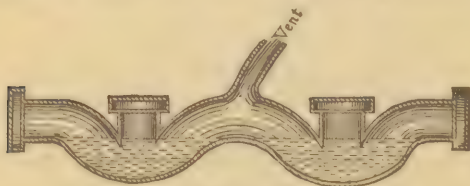


Fig. 32.

double trap (Fig. 32) with screw-plates for inspection, and a ventilating-pipe, being the now most approved arrangement.*

* Of course the *slope* of every drain, after it reaches the ground, is of great importance. One inch to the yard will afford a sufficient descent under ordinary circumstances. Very many drains have a good deal less than this; and not a few have been found, under careful inspection, to *slope the wrong way*. See Teale's *Dangers to Health*; and Report of Massachusetts Board of Health, 1879, p. 94.

In country houses, whose owners can afford carefulness for health's sake (and who, that lives in a house of his own, can not and ought not?) the same essential principles are applicable as in city residences. The most common method of rural house-drainage is, to convey waste underground to a cesspool, at a variable distance, the greater the better, from the house. By a cesspool* is generally meant a large and moderately deep well, which, if used, ought to have a removable cover for examination and emptying when needful. It is, with advantage, divided into two parts by a grating, separating solid from liquid waste. A good way of preparing the former, at proper intervals of time, for cleaning out, is, to throw over it a quantity of earth. This makes its removal less unpleasant, and affords by the mixture a very serviceable manure. The liquid portion may be directly applied to the ground; best by irrigation through sub-surface tile-pipes, open at a portion of their joints to allow of the escape of the drainage into the earth. For this use, Waring speaks very highly of Field's flushing-tank, as answering, under experience, admirably, for fertilizing a garden or cultivated field.

There are some situations which do not admit of any such distribution of waste material; for instance, at the sea-shore; where hundreds of cottages, as well

* In Scotland, this word is said to mean simply a trap.

as boarding-houses for summer occupation, sometimes spring up in a single season. At Ocean Grove, New Jersey, during the first two or three years of its settlement, driven wells for drinking-water, and other wells for house-wastes, were dug side by side, on small lots, not many feet apart. The sandy ground

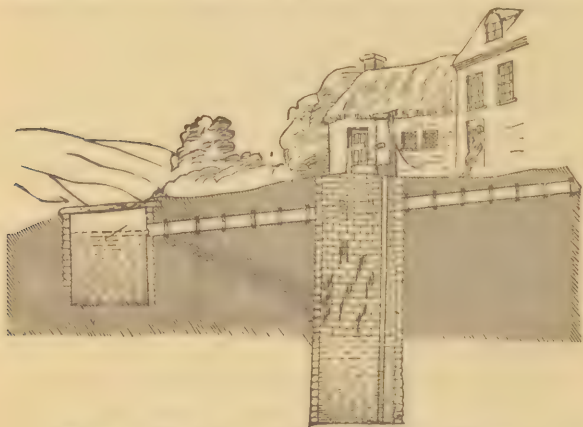


Fig. 33.—How People Drink Sewage. (Teale.)

permitted an easy mingling of waste and water supply in the common ground-water of the place. As a consequence, almost every person who visited the locality went through a seasoning, or acclimating, diarrhœa, which, especially with young children, involved sometimes quite a serious illness. Fortunately, the

Ocean Grove Association, becoming aware of the increasing contamination of their ground, took judicious measures for its protection. All waste-wells were made (as nearly as possible) water-tight; and, under strict regulation, they were all periodically cleaned out at sufficiently short intervals to avoid atmospheric contamination. A resident of the place informed me that the local diarrhœa at once disappeared under these appropriate improvements. Other watering-places have been known to suffer great disadvantage from analogous defects, not always ascertained until after they have cost some lives of visitors who had sought them as sanctuaries of health.

For the evacuation of waste-wells and cesspools in town or country, but especially in cities, the "odorless pneumatic system," most largely carried out in Amsterdam by Captain Liernur, is undoubtedly a great improvement.*

After all, however, the *ideal* method is, the return of all human waste, as soon and conveniently as possible, to the ground. Nature's own disinfectants are the *earth* and *growing plants*. Together, these are perfect in their action; and they admit, satisfactorily, of no substitution. Nor need any one be afraid of this effective transforming process, this alchemy of nature, when sewage passes *through* (not lying stag-

* See Waring on *Sanitary Drainage of Houses and Towns*, N. Y., 1878; p. 284.

nant upon) the soil on which there is abundant vegetation. The Craigentenny meadows, near Edinburgh, derive their luxuriance from sewage irrigation. At Clichy, near Paris, five thousand acres of barren sand were, by the sewage of Paris, converted into fertile fields and gardens. A manufacturer of perfumes chose this favored spot for the culture of his aromatic herbs. The finest mignonette of Covent Garden market, London, has long been grown upon sewage-watered soil. Among the *Alpes Maritimes*, ground fertilized chiefly with waste of human habitations produces, for the uses of the perfumers, an abundance of roses and violets.

CHAPTER IX.

DISINFECTION.

THE very best of all disinfectants, outside of the ground itself, are *fresh air* and *pure water*. Thorough cleanliness prevents all occasion for processes of correction ; and such prevention is infinitely to be preferred to any and all such processes, for, indeed, perfect disinfection is, in regard to the causes of some of the most dangerous diseases, hardly possible, except by the powerful influence of heat.

Almost every one now knows that odorous substances, such as cologne, do not disinfect, or even improve the air, as to healthfulness ; they only conceal or disguise the evil. If any beneficial agency can be obtained by such materials, it is to be had by *burning* aromatics, as myrrh, cloves, etc., or coffee. The latter will at least remove the unpleasant smell from a room in which the air is unavoidably affected by a bodily disorder of a person confined within it. Frequent changing of the clothing or covering of such a one, and burning or boiling every article that is soiled, are very important. No absorbent material

should, when it can be helped, be kept in a sick-room, for the same reason. Bed-curtains, window-curtains, wall-papers, and even carpets, are subject to this objection. Especially, also, everything passed from the body should be covered at once, and removed as soon as possible.*

Agents called disinfectants may act in several ways :

1. Those called *antiseptics* prevent or arrest putrefactive decay in animal and vegetable matter. Sulphate of iron and chloride of zinc are examples of this kind of action.

2. Some substances, as charcoal and lime, *absorb* gaseous emanations from decomposing bodies.

3. Others act chemically upon the results of decay, so as to make them harmless. One of the most common, unpleasant, and injurious of these resultant products is sulphuretted hydrogen, whose odor is that of rotten eggs. Against this, chlorine (in the form of chloride of lime or solution of chlorinated soda) is very effectual ; and so, also, when applied to quantities of liquids, is solution of nitrate of lead.

4. Most important, but most difficult, is the destruction of those special and subtle causes of disease, to which, because many facts make it probable that they are minute living organisms, the term "disease germs" is commonly applied.

* An uncovered chamber-vessel under a bed is an intolerable barbarism at all times.

Air is *much improved* in healthfulness by taking out of it sulphuretted hydrogen and other odorous products of mere decay. It may, however, still have left in it the contagion of small-pox or scarlet fever; the local infection of yellow fever; the miasm of autumnal remittent; or the migrating cause of epidemic cholera. To annihilate these, requires a total change of the atmosphere, as well as of the surfaces exposed to it,—such as can be effected only on a comparatively small scale; as, within a house, a railroad-car, a steamboat, or a ship.

Without dwelling longer on these generalities, we may briefly enumerate the most serviceable of disinfectants.

The cheapest (besides dry earth, referred to in our last chapter) are *quicklime*, *charcoal*, and *tar*.* These are all very effectual,—in privies, for example. All of them, however, make some deposit, which must be remembered in regard to traps, etc., where it will not do to allow accumulation. But such things have very little action on the *air*, except, it is true, when quicklime or charcoal is spread or suspended in different places within apartments. Whitewashing walls, as in cellars and kitchens, is an excellent means of “sweetening” them, which ought to be repeated often. We want, however, not unfrequently, to purify the al-

* A pint of tar, used once in a week or two, will deodorize (except with a slight odor of its own) a large privy-well.

ready contaminated air of a house. For this, the two most powerful agents are *chlorine* and *sulphurous-acid gas*. The first of these was once regarded as the only valuable disinfectant ; now, under a sort of reaction, it has come to be, with many persons, underrated. Not only will chlorine decompose sulphuretted hydrogen gas, but it will, when enough is used, also destroy *bacteria* * (the best known of minute organisms present in decaying matter); whence it may be expected to aid in the destruction of all disease-germs. But, to secure this effect, a great deal of it must be used. In a very bad state of the atmosphere, the affected rooms had better, instead, be cleared of all human beings, and fumigated with burning sulphur. For every thousand cubic feet of space, a pound and a half of sulphur should be burned,—best over a pan of water, or a vessel containing sand, to avoid the danger of fire. No one can breathe sulphurous fumes with safety. The doors and windows of rooms to be so disinfected must be closed for several hours, and then thoroughly aired before being again occupied.

Cold arrests putrefaction, and so lessens the activity of contagions and infections; but it does not destroy them. *Heat* (from 200° to 250° Fah.) is the most effectual of all disinfectant agencies—the only

* See the *Dublin Journal of Medical Science*, September, 1879, for an account of recent experimental proof of this by Dr. Notter.

perfect one. It will destroy all "disease-germs," and break up or drive off all unwholesome emanations from whatever source. It is not, however, easy or convenient to apply high heat continuously to private houses, and it has been mostly, so far, reserved for especial emergencies. Clothing exposed to any infection or contamination ought (if not bad enough to be burned) to be well boiled before being used again.

The disinfectants most commonly approved for practical use are the following:

For privy-wells or water-closets, a solution of copperas or green vitriol (sulphate of iron) may be made by diffusing ten pounds in a bucketful of water. Of this, the whole, or more, will be required to disinfect thoroughly a bad privy-well. For a bed-pan or chamber-vessel, a teacupful of the same solution will suffice each time the vessel is used. Or, for the last-named purpose, a solution of chlorinated soda may be employed, a fluidounce to a quart of water; or, crude permanganate of potassium, ten grains to the quart of water.

Carbolic acid, not long since, was lauded and trusted above almost all other disinfectants. Careful experiments have shown that it is merely an antiseptic of moderate value, with very little power to destroy bacteria or other minute organisms. This being the case, its extreme disagreeableness may well justify its being generally disused in private houses.

Chloride of lime may be safely and advantageously employed in cellars or other places where the air is not good, being placed in shallow vessels to give off chlorine gas. Vinegar, added to it, will increase its efficacy, which will not, in any case, last long. A solution of fresh chloride of lime in water will answer well to deodorize and disinfect privy-wells. Its action on metals makes it unsuitable for water-closets, kitchen-sinks, etc. Chloride of zinc has similar antiseptic properties, but does not (unless with some other chemical agent added), like chloride of lime, give off free chlorine gas.

Burnet's liquid is a solution of chloride of zinc. Labarraque's liquid is a solution of chlorinated soda. Bleaching salt is chloride of lime. Condry's liquid is solution of permanganate of potassium; Ledoyen's liquid, solution of nitrate of lead; chloralum (a very good disinfectant), solution of chloride of aluminium. Of less certainly known value are a number of recently-advertised preparations, many of them patented, which are extremely unlikely to do so much good as those above mentioned.

Above all things, however, it is to be remembered that *non-infection* is a thousand times better than *disinfection*, and absolute, universal cleanliness would insure this. The time will no doubt come, under the advance of knowledge and true civilization, when no cholera will traverse the globe from the rising to

the setting of the sun, and no yellow fever will put whole cities in mourning for their dead. As the plague has, even in the East, become a rare instead of a frequent visitant, not now, as once, invading European cities, so other terrible scourges of mankind may, and no doubt will, in time be overcome by *sanitary prevention*. In order for this to happen, every man must be the guardian of his own threshold; not only for his own advantage and safety, but also for the "common weal."

CHAPTER X.

POPULATION.

ALREADY, in the early part of this book, some facts have been given, showing a close relation between the mortality of places and the number of people aggregated together. Other facts of a similar kind abound. With more space, I might describe (were they not too horrible) the unwholesome conditions under which some thousands of people live, not only in China, India, and Egypt, but in Europe and America. We might dwell on the habits of the Icelanders, of whose children the greater part die during infancy; or, on the crowding in the continental cities of Europe; or, on that of London, where, says the *British Quarterly Review*,* at least one-half of the houses are unfit for human beings to reside in; or, nearer home, on those dreadful evils still existing in New Orleans, Memphis, and some other American cities, which make it remarkable not that yellow fever visits them, but rather that it ever

* April 1st, 1879.

spares them at all. Enough for our purpose to glance at two or three very sad but instructive examples. One of these may be a town on the naturally healthful island of Malta.

Plimpsoll, the well-known English philanthropist, has been recently investigating the sanitary condition of Valetta, where the poor population live chiefly in cellars. He says of these cellars or pits:

“They have no fireplace, and therefore no chimneys, and serve singly for a whole family,—man, wife, and children. They have no windows, and some have no other aperture of any kind than the door; and when you have reached the bottom of the well you find the floor, the solid rock, wet with urine and foul with the odor of the children. So little air reaches the bottom that the floor of the yard or well never dries, and so little light that when you are asked to enter and stand in the doorway, it is dark as pitch, and you have to light a wax match to avoid falling down the two or three steps within the doorway. . . . The excrement in many of them is put into a box over the sewer, about twenty inches square and high. It goes right down into the untrapped sewer, and there accumulates in the dry season, unmixed with ashes or dry dust of any kind.”

In one of these filthy dens, under a handsome house in the Strada Maza Muscetto, were found, in an area of sixteen hundred and ninety-two feet, three

stories or tiers of six cellars in each, and in the lowest of all above thirty people were living, thirty-nine feet *below the level of the street*.

With such sanitary arrangements, the death-rate in 1874 was 49.24 per 1000 of population. It ought to be not more than 15 or 17 per 1000.

Another case has been long familiar to readers of Carpenter's standard treatise on *Physiology*.* The island of St. Kilda, one of the Western Hebrides, when visited in 1838, had an enormous mortality of infants, *four out of every five* dying. This was explained by the way of living of the people. "Their huts were small, low-roofed, and without windows, and were used during the winter as stores for the collection of manure, which was carefully laid out upon the floor, and trodden under foot to the depth of several feet. On the other hand, the clergyman, who lived exactly as did those around him, except as to the condition of his house, brought up a family of four children in perfect health; whereas, according to the average mortality, at least three out of the four would have been dead within the first fortnight."

But we need not go farther than the lately much discussed tenement-houses of New York, for an exemplification of over-crowding and its destructive effects. Half the population of that great city live in 21,000

* Chapter on "Respiration," p. 545.

tenement-houses, and two-thirds of the deaths of the whole city occur annually among that population, mostly during childhood. Nearly half a million of people have allotted to them an average of less than seven square yards to each person. The tenement-houses are large, and often closely packed together, many rooms having no direct communication with the open air, and being never reached by a ray of sunshine from one end of the year to the other! So late as 1877, one such building (98 Mott Street) contained ninety-nine families, making in all nearly five hundred persons. Several families sometimes occupy a single room. It is not needful for us to say more in description of these dens of misery; upon which the blaze of modern sanitary inquiry has now been fully turned, so that philanthropy and civic prudence have united to abate their evils.

An extraordinary fact is, that the poorer portion of those brought up amid such circumstances are often *unwilling* to have them improved. They must be helped and taught gradually; they seem almost like owls or bats brought out into daylight, when any one attempts to better their condition. Says Dr. Stephen Smith (*Sanitarian*, July, 1875, p. 155): "The family reared in a cellar resists every effort to induce it to take rooms on the first floor. The struggle of the Board of Health to vacate cellars and compel the underground population to live above ground, has been

carried on with varying success for many years. Again, we find a family always accustomed to a rear tenement will never take the front, and one always occupying a single room will be found averse to occupying two rooms."

Yet, when once an improvement has been made, they become aware of its benefits, and are brought to assist in their extension. In 1866 a reform was begun in New York, through which, according to Prof. Chandler, down to the present year, thirteen thousand lives have been saved.

By the aid of sea-side homes for sick children, excursions to the country, and on the water, free medical attendance and sanitary advice, this lowering of mortality in tenement-houses goes on more and more rapidly. In 1876, 3060 deaths occurred amongst them from summer diarrhoeal diseases; in 1879, 2084—a reduction of nearly a thousand in this death-rate alone.

Besides some regulations referred to on a previous page, it is now enjoined, by the New York Tenement-House Law, that the space between floor and ceiling must be in every room at least eight feet. Every bedroom must have direct communication with the outside air, and six hundred cubic feet of air-space must be allowed for every occupant. When this last enactment comes to be fairly carried out among the hundreds of thousands now packed together with an

average, in some blocks, of from one to two hundred in a single house, the sanitary millennium will almost have arrived. Now, upon two miles of Fifth Avenue, four hundred families dwell in wealth and comfort. Less than two hundred yards from this elegant thoroughfare, a single block of tenement-houses has long contained seven hundred families, aggregating thirty-five hundred souls. How much disease and how many deaths in Fifth Avenue may have been derived from such a block!

It has been shown that no skill or ingenuity can suffice to build a healthy and comfortable tenement-house of several stories for a large number of people upon a lot twenty-five by a hundred feet. The best that can be done with such lots is, to erect upon them (*at most*, two or three on a single lot) small two- or three-storied dwellings of improved construction. This has been done lately in Brooklyn, each house costing about \$1100. These, at a rent varying from \$13 to \$20 per month, will produce a fair return to their owners. Upon this topic more will be said in our next and concluding chapter.

Boston as well as New York has long been overcrowded upon the tenement-house system; and some smaller manufacturing cities of New England have had of late an increasing excess of population. A committee of the American Social Science Association not long since reported that in Boston the average pro-

portion is more than eight persons to a dwelling, some of the old wards having an average of eleven and twelve. In Fall River it is between ten and eleven. In New York, according to the census of 1870, it was nearly fifteen persons to each dwelling; in nine wards, twenty-two. At the same time, Philadelphia had one house for every six persons, as the average for the whole city; while its worse wards had one house for every eight.* No wonder, then, that this city has been called the "City of Homes!"

* The actual number of houses in 1870 was, in New York, 64,440; in Philadelphia, 112,366. Population of the former city, nearly a million; of the latter, about 675,000. In 1876, by count of the police, there were in Philadelphia nearly 144,000 houses. In New York, by the State Census of 1875, the number of dwellings was 67,126; population, 1,041,886; average for each house, 15.52. The average for each house during the same year in London was 7.8 persons. (See *Report for 1878*, by J. T. Nagle, M. D.; *Hospital Gazette*, Dec. 13, 1879.)

CHAPTER XI.

WORKING-MEN'S HOMES.

IN Dr. B. W. Richardson's imaginary model city, *Hygeia*, a method is proposed by which the work of men and women may be kept quite apart from their dwellings. This separation is to be effected by the establishment of blocks of buildings expressly for the purpose; where, in appropriate rooms, the tailor, dress-maker, lace-maker, etc., may go through with his or her daily task, and return home when it is done. Day-nurseries, meanwhile, are to take care of the children while their mothers are away at work. This is carrying the co-operative principle very far; too far, probably, ever to meet with universal favor or success. But a certain degree of approach to it already exists in connection with many avocations; and the question of the maintenance of good homes for working-people has become one of the most pressing in sanitary and social science.

Naturally, most workmen wish to have their dwellings near their places of business, so as to save time, effort, and expense in going from the one to the other.

With those whose occupations are sedentary, involving but little muscular labor, it is really better that there should be distance enough between home and work to secure some exercise in the open air in the morning and evening walk. But with those whose labor is prolonged and fatiguing, it is desirable that the home should be either near the place of work, or accessible by some cheap and rapid conveyance.

Working-men's trains, with reduced fares, now run to and from several of the largest cities in England, and in our own country; and they are very useful. Horse-cars, in Philadelphia especially, render a similar kind of service, though with much less saving of time.

Where ground is greatly in demand for business purposes, it is impossible to get a good interest from dwellings upon it, unless they pay a high rent. If this rent is to be obtained from poor tenants, there must be a great many of them in one building. Other portions of large cities are usually rendered unavailable for homes for the working-class, by the high prices growing out of social preferences for localities. After awhile, the valuation of health will prevail more reasonably than now, and then a town-lot on the highest and most open quarter of the city will command at least as good a price as one on lower ground, closely built with marble or brown-stone fronts, on a fashionable street. Such a comparative

equalization of land-values may, before long, aid in making it practicable for capitalists, or well-to-do artisans on a smaller scale, to erect houses in good parts of the town, at a small or moderate expense—such as will be within the reach of workmen who must live not very far from city establishments.

But the best and highest aim always will be for every man to own his dwelling. Building associations admirably promote this result. Some of these, in London, have been started and managed by men of capital, for the benefit of the poor. Others are truly co-operative. This is the character of those which have become very successful and useful in Philadelphia.

Ground-rents, irredeemable so long as the interest is paid, make the purchase of land for building more practicable. One who owns a small lot (say eighteen by ninety feet, on a fifty-foot street), on which there is a ground-rent, may join a Building Association; and, by paying one dollar a month, he may have opportunity to borrow from the association, at a moderate premium and interest, enough money to put up a small house. It may be of brick—fourteen and a half feet front (leaving a passage at the side of three and a half feet) and thirty-two feet deep. Thus, by paying dues, in all amounting monthly to about twelve dollars and a half, he is enabled, in eight, ten, or twelve years, to clear off his indebtedness on the

house, and have it for his possession as well as his home. Multitudes of such two- and three-storied houses, with two (seldom three) rooms on a floor, and mostly owned by their occupants, are to be seen in rows and blocks in many parts of Philadelphia. George Peabody did an immense amount of good, by presenting a large sum of money for the erection of model lodging-houses in London for the poor; but much more advantage has resulted from this happy series of enterprises, which have made it possible for thousands to erect homes for themselves. Morals, as well as comforts, are thus often signally improved. Of course, philanthropists may and must, especially at first, assist and direct such reforms. Prince Albert was, herein, a truly noble example and leader. John Ruskin and Octavia Hill in London, the Board of "Trustees" in Glasgow, and the "Association of Physicians" in Copenhagen, have alike shown not only that the comforts and decency of the very poor can be thus greatly aided, but that vice and intemperance are thereby discouraged, and municipal order promoted — and all this without loss, indeed with a very fair return to the owners on their investments.

Yet, alas, how many of the poor, in all our cities, still need to be lifted out of their squalidness, and taught how to live! For these, there is excellent training, as well as health-giving and much enjoyment, in the summer-days' excursions and the "coun-

try week."* In the latter, especially, there is a rich combination of all these advantages. Show the unwilling but ignorant prisoner of Five Points or Alaska Street how the humble farmer or farm-laborer lives, in a neat and airy cottage among green fields, and he or she *must* be inspired with longings for something better for himself or herself, and for their offspring. The sights and odors of the fresh, open country will long live in the dreams of children who are taken out to be refreshed and revived by them; and then they cannot so easily afterwards be content without cleanliness, which is possible everywhere, and thus sweetness, in the working-man's home. They will be better, safer, more patriotic citizens therefor; and so it is the interest, nay, almost the necessity, of every member of the wealthier class to aid and encourage all that can be done toward so important a reform. Even a single day's lesson in healthy living will help this much.

Six hours of sunshine! six bright hours of gladness!

Six hours of joy 'mongst grass, and flowers, and trees;

Six hours' escape from want, and woe, and sadness;

Six hours of butterflies, and birds, and bees!

* This is an arrangement by which families living in the country receive, for a week or more at a time, children of the poor from the city. It is managed by a voluntary organization of benevolent ladies, who have reported excellent results from it.

That's all they pray for ; all these tiny creatures,
Stunted and squalid, ask of you one day,
To let God's breezes fan their wee, wan features,—
One day from their dark homes to get away.

One day to leave the fetid court and alley,
To breathe pure air, to hear the wild bird's song ;
One day to track the brook adown the valley ;
One day ! — Oh ! say, my brothers, is 't too long ? *

* From *London Truth*, 1879.

CHIEF WORKS

FOR

Consultation on the Subjects of this Primer.

PARKES' *Practical Hygiene*.

BUCK'S *Hygiene and Public Health*, Vol. I.

LEEDS *on Ventilation*.

PETTENKOFER *on Air in Relation to Clothing, Soil,
and Dwellings*.

WYMAN'S *Practical Treatise on Ventilation*.

Hygeia, a Model City of Health,

By B. W. RICHARDSON, M.D.

Healthy Houses, by FLEEMING JENKIN.

Sanitary Arrangements for Dwellings, by W. EASSIE.

Dulce Domum; or, The Plumber and Sanitary Houses,

By S. S. HELLYER.

Plumbing and House Drainage, by W. P. BUCHAN.

Sanitary Drainage of Houses, by G. E. WARING.

Dangers to Health, by T. PRIDGIN TEALE.

Annual Reports of Massachusetts Board of Health.

The Sanitarian; a Monthly Magazine of Health.

The Plumber and Sanitary Engineer; a Biweekly
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